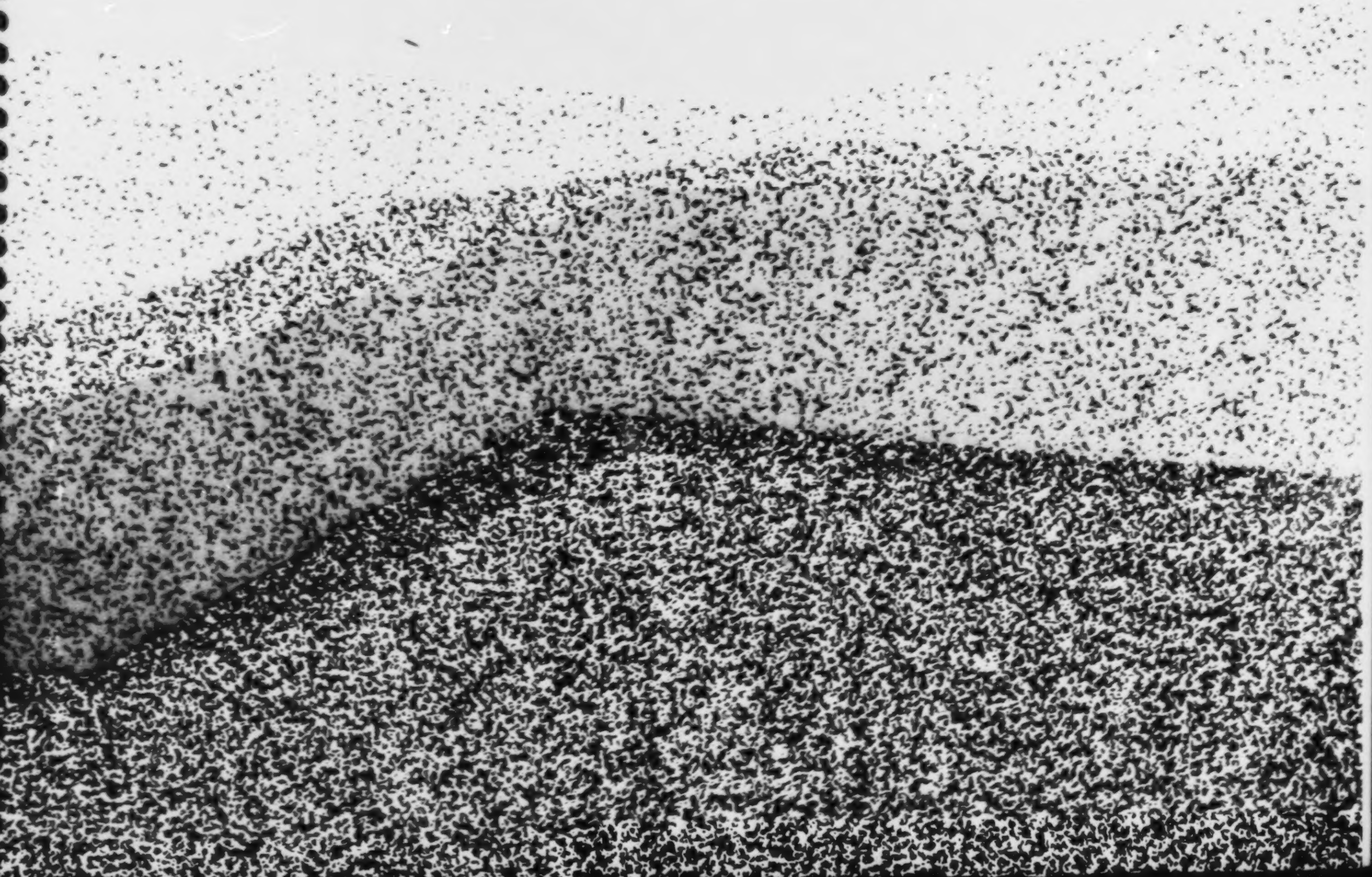
Centre for
Resource Studies

Queen's University
Kingston, Ontario

Mineral Exploration and Mine Development Potential In Ontario: Economic Guidelines For Government Policy

BRIAN MACKENZIE
MICHEL BILODEAU
MICHAEL DOGGETT

Technical Paper No. 9



MINERAL EXPLORATION AND MINE DEVELOPMENT POTENTIAL IN ONTARIO: ECONOMIC GUIDELINES FOR GOVERNMENT POLICY

Brian Mackenzie
Michel Bilodeau
Michael Doggett

Centre for Resource Studies
Technical Paper No. 9

April 1989

Canadian Cataloguing in Publication Data

Mackenzie, Brian W., 1939-
Mineral exploration and mine development potential in Ontario

(Technical paper, ISSN 0821-0675; no. 9)
ISBN 0-88757-096-8

1. Mines and mineral resources - Ontario. 2. Gold mines and mining - Economic aspects - Ontario. 3. mineral industries - Government policy - Ontario. 4. Gold mines and mining - Government policy - Ontario. 5. Prospecting - Ontario - Costs. I. Bilodeau, Michel L., 1948- II. Doggett, Michael. III. Queen's University (Kingston, Ontario). Centre for Resource Studies. IV. Title. V. Series: Technical paper (Queen's University (Kingston, Ontario). Centre for Resource Studies); no. 9

HD9506.C33058 1989 338.2'3'09713 C89-094366-4

© Centre for Resource Studies, 1989
Queen's University

91-04831/

PREFACE

This study was prepared under contract to the Mineral Development and Lands Branch of the Ontario Ministry of Northern Development and Mines. It was conducted in parallel with a similar study commissioned by the Government of Newfoundland. Both studies have contributed to expansion and updating of the CRS Canada-wide mineral deposit data base, which is used by CRS for a wide range of research on the implications of corporate and public policies and programs affecting the mineral sector.

Views expressed are those of the authors, and do not necessarily reflect the views of CRS, its sponsors, or the Ontario Ministry of Northern Development and Mines.

Margot J. Wojciechowski
Centre for Resource Studies

ACKNOWLEDGEMENTS

The support of the Canadian mining companies, which since the mid-1970s have provided the mineral deposit information necessary for our CRS data base, is once again gratefully acknowledged. For the present update and extension, we would like particularly to thank the following: Michael Power and George Penna, Noranda; Chris Jennings and David Crowley, Selco Division of BP Canada; Chris Cowan and Jim McFaull, United Keno Hill Mines; and Alastair Walker, Hudson Bay Mining and Smelting.

We would also like to express our appreciation to the government officials who contributed to the study: Donald Cranstone, Don Law-West, and Andy Sozanski, Mineral Policy Sector, Energy, Mines and Resources Canada; Yoon Hwang, Statistics Canada; Charley Lee and Bob Owen, Ontario Geological Survey; John Gammon, Gerry Anders, and John Malczak, Mineral Development and Lands Branch, Ontario Ministry of Northern Development and Mines.

We thank Alan O'Hara for developing the costing relationships utilized; and Yearn Park, Department of Mining and Metallurgical Engineering, McGill University, for assisting with the data processing and computer analysis.

Brian Fenoulhet, Garth Pierce, and Peter Telford read an earlier draft of the manuscript and made helpful comments which are gratefully acknowledged.

Brian Mackenzie
Michael Doggett
Kingston, Ontario

Michel Bilodeau
Montreal, Quebec

SUMMARY

The objective of the study is to assess and compare the economic potential of base metal and gold exploration and mine development in Ontario as a basis for mineral policy formulation. While the results are of an indicative nature, depending on assumptions concerning the uncertain future, they provide a meaningful overall picture of mining potential in the province.

The Canada-wide data base for this appraisal includes $7.7 billion of exploration expenditures, and deposit-specific estimates for 437 base metal and gold deposits discovered during the 40-year period 1946-85 as a result of those expenditures. Ontario accounts for $1.4 billion of the total exploration investment and 70 of the deposits discovered. The study methodology assesses this experience in the context of present-day economic and technological conditions. Money values are expressed in constant 1987 Canadian dollars.

The economic potential for gold and base metal exploration and mine development in Ontario is shown to be substantial. For anticipated future conditions, long-term potential, measured from the start of mineral exploration, is characterized by an expected value of $80 million for each economic deposit discovered. Medium-term potential, measured from the start of mine development, is typified by a net present value of $177 million per economic deposit. The enhancement in potential value which occurs between exploration and development, $97 million on average for each economic deposit in this case, illustrates exploration's economic contribution to the mineral supply process.

The representative characteristics assessed for mineral exploration and mine development in Ontario, such as those summarized above, are broad generalizations across a wide range of experience. Several other more specific features are also highlighted:

- a high degree of variability is shown in the return characteristics of economic deposits around the composite values appraised. For example, a 100-fold difference in net present value is shown between the lower-decile and upper-decile economic deposits ($4 million and $391 million respectively around the mean value of $177 million);

- base metal and gold discoveries have quite different economic make-ups. Historical experience in Ontario suggests that an economic base metal deposit is 3 times more costly to find and delineate on average, but tends to be 5 times larger as well as more profitable to develop than an economic gold deposit;

- the economic potential of mineral exploration and mine development in Ontario is found to be particularly sensitive to future metal prices. Flexibility should therefore be incorporated in government plans and policies to accommodate the resolution of price uncertainties with time;

- the Kidd Creek base metal deposit and the Hemlo gold deposit are found to make the difference between Ontario being a highly prospective and profitable province for exploration and what would otherwise be a marginal environment on average. The possibility that any exploration program can lead to another multi-billion dollar discovery of this calibre provides a great investment incentive.

Study results show that Ontario has a strong competitive position in the shield region and in Canada. This favourable position is mainly attributable to the discovery of the Hemlo and Kidd Creek deposits within the province's boundaries.

A marked deterioration is found in the potential value of base metal exploration in Ontario and throughout Canada during the past 20 years, culminating in uneconomic results for 1976-85, the most recent decade analyzed. The economic potential of gold exploration, on the other hand, appears to be improving with time. This time trend is somewhat tenuous however, because so much of the gold activity is concentrated in the 1980s.

Ontario's taxation policies are shown to have a substantial negative impact on investment incentive. For example, given anticipated future conditions, the expected value of exploration per economic discovery is reduced from the assessed potential value of $80 million to $45 million after tax, and the expected net present value associated with mine development is likewise reduced from $177 million potentially to an after-tax value of $42 million.

The three-year tax exempt period for Ontario mining tax, introduced in 1987, is shown to have a significant positive effect on the after-tax incentive for exploration and development. Together with other tax policies, Ontario's taxation regime tends to rank towards the middle of the Canadian inter-provincial league. The overall incidence of taxation in Ontario is shown to be significantly lower than in British Columbia, Manitoba, Newfoundland, and Saskatchewan; about the same as in Quebec and New Brunswick; and somewhat higher than in Alberta, the Northwest Territories, Nova Scotia, and the Yukon Territory. While federal and provincial corporate income tax in Ontario tend to be on the high side, Ontario is found to be in a very strong competitive position with respect to provincial mining tax.

The potential values assessed in the study provide a portrait of the mineral supply process that can be applied when looking ahead to describe the distinctive economic characteristics of mineral exploration and mine development in Ontario for government policy analysis. More generally, the study illustrates the type of data base, evaluation procedure, and economic assessments that can be developed and used on an on-going basis. The authors recommend that the Ontario government consider adopting this type of approach to support mineral policy formulation and decision making.

CONTENTS

Preface / iii

Acknowledgements / iv

Summary / v

1. Introduction / 1
    - Background / 1
    - Objective and Scope / 2
    - Organization of Study / 3

2. Appraising the Potential Value of Mining: The Methodology / 5
    - The Mineral Supply Process / 5
    - Potential Value of Mining / 8
    - Mineral Exploration Economics / 9
        - Expected Value Criteria / 10
        - Risk Considerations / 13
    - Mine Development Economics / 15
        - Expected Value Criteria / 16
        - Risk Considerations / 18
    - Evaluation Procedure / 19
    - Summing Up / 22

3. Base Metal and Gold Exploration and Development in Ontario, the Shield Region and Canada: The Data Base / 23
    - Study Specifications / 23
    - Total Exploration Expenditures / 23
    - Annual Exploration Budget Rate / 25
    - Possible Economic Discoveries for Evaluation / 27
    - General Market Estimates / 29
    - Estimates for Individual Deposits / 29
    - Critique of the Data Base / 36
    - Data Processing / 37
    - Variants for Analysis / 37

4. Potential Value of Mineral Exploration and Mine Development in Ontario / 39
  - Mineral Exploration Economics / 39
    - Base Case Results / 39
    - Comparison of Base Metal and Gold Exploration Potential / 41
  - Mine Development Economics / 44
    - Base Case Results / 44
    - Variability of Returns for Individual Deposits / 46
    - Comparison of Base Metal and Gold Mine Development Potential / 48
  - Summing Up / 50

5. Sensitivity of Potential Values to Key Study Parameters / 53
  - Mineral Exploration Economics / 53
    - Metal Price Variants / 53
    - Variants with Respect to the Annual Exploration Budget / 55
    - Cost of Capital Variants / 57
    - Effect of the Multi-Billion-Dollar Discovery / 58
  - Mine Development Economics / 59
  - Summing Up / 62

6. Ontario's Competitive Standing in the Shield Region and in Canada / 63
  - Mineral Exploration Economics / 63
    - Base Metal and Gold Exploration / 63
    - Base Metal Exploration / 65
    - Gold Exploration / 69
  - Mine Development Economics / 69
    - Average Returns / 69
    - Variability of Returns / 72
    - Comparative Endowment and Return Characteristics for Deposits Discovered Before and During the Study Period / 76
  - Time Trends / 79
  - Summing Up / 83

7. Mining Taxation Considerations / 84
    Tax Assumptions / 84
        Inflation / 84
        Exploration Expenditures / 84
        Development and Production Phases / 85
    Base Case Results / 86
    Metal Price Variants / 90
    Ontario's Competitive Standing / 90
    Tax Write-Off Variants / 90
    Effect of the Three-Year Tax-Exempt Period / 94
    Inter-Provincial Comparison / 94
    Summing Up / 100

8. Conclusion / 103

Appendix I: Inflation Multiplier Series Used in Study / 107

Appendix II: Exploration Expenditure Estimates / 109
    Metallic Mineral Exploration / 109
    Exploration for Non-Study Metals / 110
    Gold Exploration / 111
    Base Metal Exploration / 112
    Exploration in the Shield Region / 113
    Constant Dollar Exploration Expenditures / 113
    Exploration Expenditure Data Sources / 115

Appendix III: Possible Economic Discoveries for Evaluation / 122
    Base Metal Deposits / 122
        Ontario / 122
        Other Shield Region / 123
        Other Canada / 127
    Gold Deposits / 133
        Ontario / 133
        Other Shield Region / 134
        Other Canada / 136

Appendix IV: Other Discoveries Considered but Excluded from the Evaluation / 137
    Base Metal Deposits / 137
        Ontario / 137
        Other Shield Region / 139
        Other Canada / 141
    Gold Deposits / 147
        Ontario / 147
        Other Shield Region / 148
        Other Canada / 149

Appendix V: General Revenue and Cost Relationships / 150
    Smelter Return Conditions / 150
    Concentrate Transportation Costs / 152
    Gold Marketing Charges / 153
    General Deposit Costing Relationships / 153

Appendix VI: Income and Mining Taxation Systems / 156
    Taxation Systems in Ontario / 156
    Provincial and Territorial Corporate Income Taxation Elsewhere in Canada / 161
    Provincial and Territorial Mining Taxation Elsewhere in Canada / 163
    Rates Used to Calculate Tax Credits Associated with Exploration Expenditures / 174

The Authors / 176

Centre for Resource Studies / 177

CRS Publications / 178

TABLES

1. Total Base Metal and Gold Exploration Expenditures / 26
2. Number of Possible Economic Deposits for Evaluation / 28
3. Long-Term Price Variants for Mineral Commodities / 30
4. Average Mine Development Parameters for Base Metal and Gold Deposits / 35
5. Average Cash Flow Characteristics for an Economic Deposit Under Base Case Conditions / 40
6. Expected Values for Mineral Exploration in Ontario Under Base Case Conditions / 41
7. Average Cash Flow Characteristics for an Economic Deposit by Commodity Grouping / 43
8. Expected Values for Mineral Exploration in Ontario by Commodity Grouping / 43
9. Economic Deposits Assessed in Ontario for Base Case Conditions / 46
10. Variability of the Return for Economic Deposits in Ontario / 47
11. Expected Values for Mine Development in Ontario by Commodity Grouping / 50
12. Comparison of Base Metal and Gold Mine Development: Variability of the Return for Economic Deposits / 51
13. Expected Values for Mineral Exploration in Ontario as a Function of Metal Price / 55
14. Expected Values for Mineral Exploration in Ontario as a Function of the Annual Exploration Budget / 56
15. Expected Values for Mineral Exploration in Ontario as a Function of the Cost of Capital / 57
16. Expected Values for Mineral Exploration in Ontario: Effect of the Multi-Billion Dollar Discovery / 60
17. Sensitivity of Potential Values of Mine Development to Key Study Parameters / 61
18. Ontario's Competitive Standing: Average Cash Flow Characteristics for Economic Deposits / 63
19. Ontario's Competitive Standing: Expected Values for Mineral Exploration / 65

20. Ontario's Competitive Standing: Average Cash Flow Characteristics for an Economic Deposit by Commodity Grouping / 67
21. Ontario's Competitive Standing: Expected Values for Mineral Exploration by Commodity Grouping / 67
22. Ontario's Competitive Standing: Expected Values for Mine Development / 71
23. Ontario's Competitive Standing: Expected Values for Mine Development by Commodity Grouping / 71
24. Ontario's Competitive Standing: Variability of the Return for Economic Deposits / 73
25. Ontario's Competitive Standing: Variability of the Return for Economic Base Metal Deposits / 74
26. Ontario's Competitive Standing: Variability of the Return for Economic Gold Deposits / 75
27. Ontario's Competitive Standing: Time Trends in Average Base Metal Endowment Characteristics for Possible Economic Discoveries / 77
28. Ontario's Competitive Standing: Time Trends in Average Base Metal Return Characteristics for Economic Discoveries / 78
29. Ontario's Competitive Standing: Time Trends in Expected Values for Mineral Exploration / 80
30. Ontario's Competitive Standing: Time Trends in Expected Values for Base Metal Exploration / 81
31. Ontario's Competitive Standing: Time Trends in Expected Values for Gold Exploration / 82
32. Average After-Tax Cash Flow Characteristics for an Economic Deposit Under Base Case Conditions / 88
33. After-Tax Expected Values for Mineral Exploration in Ontario Under Base Case Conditions / 88
34. After-Tax Expected Values for Mine Development in Ontario Under Base Case Conditions / 89
35. After-Tax Expected Values for Mineral Exploration in Ontario as a Function of Metal Price / 91
36. Ontario's Competitive Standing: After-Tax Expected Values for Mineral Exploration / 92
37. Ontario's Competitive Standing: After-Tax Expected Values for Mine Development / 93
38. After-Tax Expected Values for Mineral Exploration in Ontario as a Function of Tax Write-Off Variants / 95

39. After-Tax Expected Values for Mineral Exploration in Ontario: Effect of the Three-Year Tax Exempt Period / 96
40. After-Tax Expected Values for Mine Development in Ontario: Effect of the Three-Year Tax Exempt Period / 96
41. Ontario's Competitive Standing: Inter-Provincial Comparison of After-Tax Values / 97
42. Exploration Expenditures in Canada (current dollars) / 116
43. Exploration Expenditures in Ontario (current dollars) / 117
44. Exploration Expenditures in the Shield Region (current dollars) / 118
45. Exploration Expenditures in Canada (constant 1987 dollars) / 119
46. Exploration Expenditures in Ontario (constant 1987 dollars) / 120
47. Exploration Expenditures in the Shield Region (constant 1987 dollars) / 121

ILLUSTRATIONS

1. The Mineral Supply Process / 6
2. Potential Value of Mineral Exploration: Time Distribution of Average Cash Flows for an Economic Discovery / 11
3. After-Tax Value of Mineral Exploration: Time Distribution of Average Cash Flows for an Economic Discovery / 11
4. Cumulative Probability Distribution and Key Statistics of a Return Parameter for Economic Deposits / 15
5. Potential Value of Mine Development: Time Distribution of Average Cash Flows for an Economic Mineral Deposit / 17
6. After-Tax Value of Mine Development: Time Distribution of Average Cash Flows for an Economic Mineral Deposit / 17
7. Procedure for Evaluating the Potential Value of Mineral Supply / 21
8. Deposit Estimate Form / 32
9. Time Distribution of Average Cash Flows for an Economic Deposit: Base Case Conditions / 40
10. Time Distributions of Average Cash Flows for an Economic Deposit: Comparison of Base Metal and Gold Exploration / 42
11. Time Distribution of Average Cash Flows for an Economic Deposit as Viewed from the Start of Mine Development: Base Case Conditions / 45
12. Time Distributions of Average Cash Flows for an Economic Deposit as Viewed from the Start of Mine Development: Comparison of Base Metal and Gold Mine Development / 49
13. Time Distributions of Average Cash Flows for an Economic Deposit as a Function of Metal Price / 54
14. Time Distributions of Average Cash Flows for an Economic Deposit: Effect of the Multi-Billion Dollar Discovery / 59
15. Time Distributions of Average Cash Flows for an Economic Deposit: Ontario's Competitive Standing / 64
16. Time Distributions of Average Cash Flows for An Economic Base Metal Deposit: Ontario's Competitive Standing / 66
17. Time Distributions of Average Cash Flows for an Economic Gold Deposit: Ontario's Competitive Standing / 70
18. After-Tax Time Distribution of Average Cash Flows for an Economic Deposit: Base Case Conditions / 87
19. Inter-Provincial Comparison of Total Tax Payments: Ontario's Competitive Standing / 99
20. Inter-Provincial Comparison of Tax Payments by Component: Ontario's Competitive Standing / 101

1. INTRODUCTION

Background

A process of information assembly and analysis is necessary to support mineral policy decisions. The basic components that must be present if the support process is to respond efficiently to policy needs are:

- an evaluation procedure to assess the potential value of mineral supply;
- an empirical data base that documents mineral exploration, development, and production activities within the jurisdiction concerned;
- on-going capability to integrate the data base and the methodology to produce economic assessments;
- appraisal of the direct effects of mineral policy options on the potential value of mineral supply.

Mineral exploration and mine development are integral parts of the mineral supply process. The discovery and delineation of economic deposits, the successful result of exploration, is the necessary starting point for mine development. These two types of activity represent, respectively, the long-term and medium-term phases of the supply process.

While exploration and development are directly connected, their economic characteristics are quite different and should be clearly distinguished. Perhaps because of this, experience suggests that the size and type of organization best suited for mineral exploration may be different than the corporate requirements for successful mine development.

Government policy analysis normally tends to focus on a "typical" economic deposit at the mine development stage. Appropriate policy options are overlain on the typical deposit profile, and their direct economic effects are evaluated and analyzed.

This standard approach is deficient in three important respects. First, the "typical" deposit profile is as a matter of convenience invariably based on an actual deposit situation rather than being synthesized from the characteristics of all economic deposits. Second, the variability in economic potential among deposits is not considered. Third, the exploration activity required as a prerequisite for mine development is ignored.

For realistic government policy analysis, these three features must be examined. An average or expected deposit profile can only be objectively determined as a composite of all economic deposits. This procedure also provides the basis for appraising economic effects associated with the variability of potential value among deposits. Finally, in the long term, the economics of mineral supply must be assessed from the start of exploration.

Objective and Scope

The objective of the study is to assess and compare the economics of mineral exploration and mine development with particular reference to base metal and gold supply in Ontario. Results are analyzed with a view to providing economic guidelines for the formulation of Ontario government policy.

The study methodology is based on data compiled for a large number of deposits over a relevant historical time period. Assessment of the economics of mineral exploration and mine development is made by placing this experience in the context of present-day economic and technological conditions. In other words, if we were to begin to look today for the deposits which were in fact discovered during the selected historical period, how long would it take and how much would it cost to find and delineate them? Which of these discoveries would justify development? What revenues and costs would be associated with development and production of the economic deposits? How does the economics of mineral exploration compare with the economics of mine development? In this way, we are endeavouring to use historical experience to provide the Ontario government with policy and planning guidelines for the future.

The assessments of base metal and gold exploration and development are based on the 40-year period 1946-85. This time period is subdivided into four decades - 1946-55, 1956-65, 1966-75, and 1976-85 - to examine time trends in the economics of the mineral supply process.

Money values unless otherwise specified are expressed in constant 1987 Canadian dollars. Appraisals in the main part of the study are made on a potential value, before-tax basis, including all direct costs and revenues associated with exploration and development. The focus is on base metal and gold activities in Ontario, comparing the province's performance with similar assessments for the shield region, and for Canada.

Appraisals are then made on an after-tax basis, considering the application of federal and Ontario income and mining taxation systems to the overall potential values. The effect of the three-year tax exempt period for Ontario mining tax introduced in 1987 is examined. A comparison is made of the level and components of mining tax payments in Ontario relative to other provinces and territories. These results illustrate the application of the study data base and evaluation procedure to analyze mineral policy issues.

Organization of Study

An overview of the study, its main findings, and policy implications are first presented in summary form.

Chapter 2 describes the evaluation procedure developed to assess the economic potential of mineral exploration and mine development. The methodology provides terms of reference for assembling the study data base, and for evaluating and explaining results.

The data base for base metal and gold exploration and development activities in Ontario, the shield region, and Canada is presented in chapter 3. The information assembled includes the estimation of total exploration expenditures, a listing of possible economic discoveries for evaluation, projections of long-term metal prices, the estimation of ore reserves and costs for individual deposits based on historical experience, and the development of generalized net smelter return and deposit costing relationships.

Chapter 4 appraises and compares the potential value of base metal and gold exploration and development in Ontario. The sensitivity of economic criteria to possible variations in metal prices, the cost of capital, and the annual exploration budget is then examined in chapter 5. The impact of the Kidd Creek and Hemlo deposits on overall study results is also considered. Ontario's competitive standing in the shield region and in Canada is appraised in chapter 6.

Chapter 7 considers the impact of mining taxation on the potential values assessed in chapter 4. The effect of the three-year tax exempt period introduced in 1987 is evaluated. Also, a comparison is made of the incidence and components of mining taxation in Ontario relative to those associated with other Canadian provinces and territories.

Several matters summarized in the text are described in greater detail in the appendices. The inflation multiplier series applied in the study is shown in appendix I. Appendix II describes the method adopted for estimating base metal and gold exploration expenditures and gives more detailed breakdowns. The possible economic discoveries included in the evaluation are listed and classified in appendix III. Other discoveries considered but excluded from the evaluation are itemized in appendix IV. Appendix V describes the general revenue and cost relationships utilized. Finally, the 1987 taxation systems applied to determine the after-tax value of base metal and gold mining are outlined in appendix VI.

2. APPRAISING THE POTENTIAL VALUE OF MINING: THE METHODOLOGY

The purpose of this chapter is to describe the evaluation procedure used to assess the economic potential of base metal and gold mining in Ontario. The concept of "the mineral supply process" which follows provides a framework for appraising the potential value of mining for this purpose.

The Mineral Supply Process

The mineral supply process consists of a series of activities by which minerals are converted from unknown geologic resources to marketable commodities. As portrayed in figure 1 and described below, the major phases of activity in the process are (1) exploration, (2) development, and (3) production. The basic stimuli of this process are the physical occurrence of mineral deposits in nature and the demand for mineral commodities in the economy. A positive response from both exploration geologists and market researchers to particular geologic and market factors combine to guide the selection of environments for exploration.

Mineral exploration, the first phase of mineral supply, is a sequential, information-gathering process consisting of two stages: primary exploration and delineation. During the primary exploration stage, potentially favourable areas of land are selected within an environment of interest and then are subjected to a series of geological, geophysical, and geochemical tests. Successful primary exploration results in the discovery of one or more mineral occurrences, although at this stage the ultimate size and value of any occurrence is unknown.

The mineral occurrences discovered provide justification for delineation, the second stage of exploration, during which information is provided for estimating the size, grade, and physical characteristics of the discovery that are relevant to mineral or metal recovery. The objective of delineation is the identification of possible economic discoveries for evaluation. When the delineation stage has yielded enough information on a particular deposit, a decision is made about developing the deposit to production. If the characteristics of the delineated deposit warrant mine development, the mineral exploration phase is com-

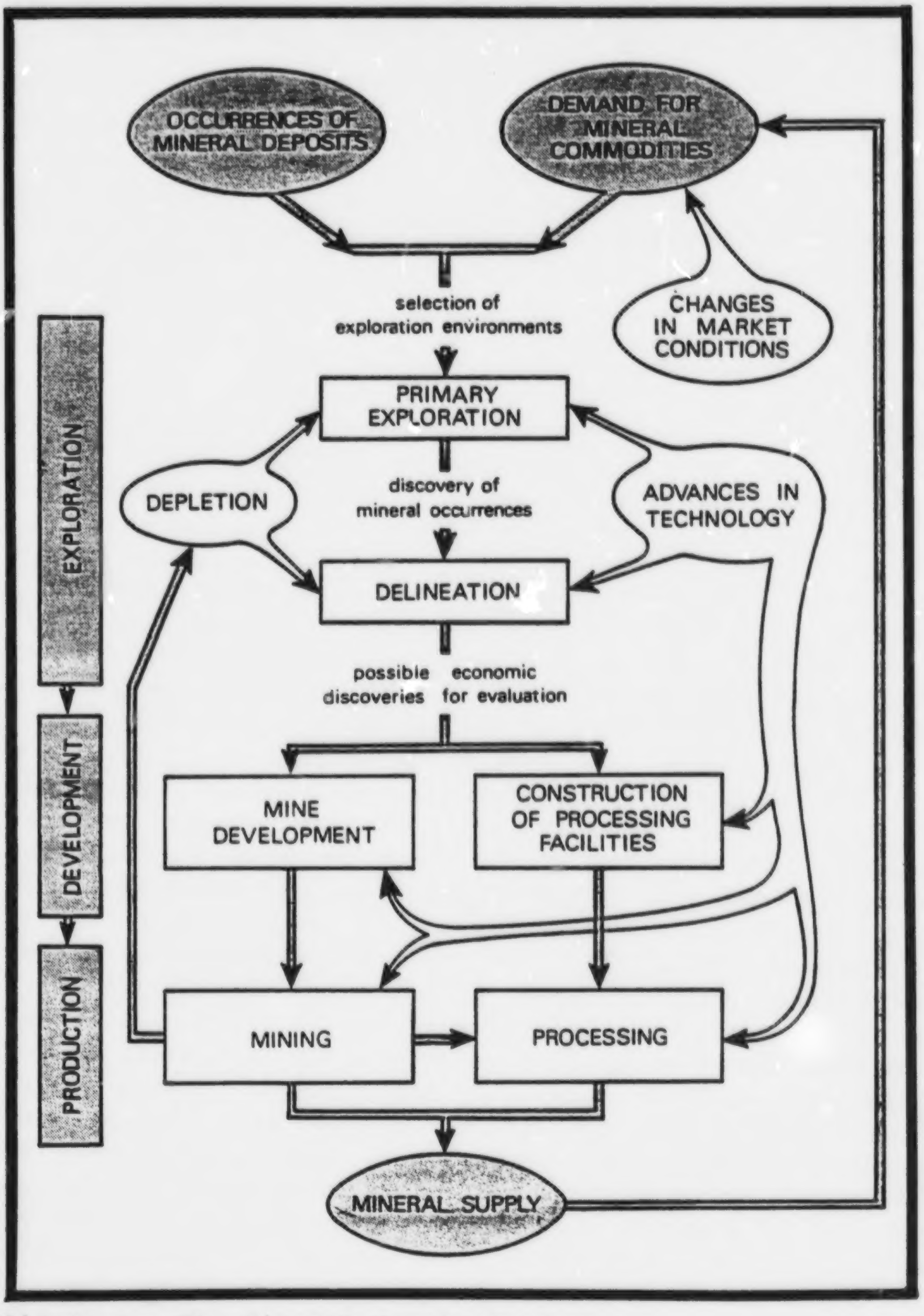

OCCURRENCES OF MINERAL DEPOSITS
DEMAND FOR MINERAL COMMODITIES
selection of exploration environments
CHANGES IN MARKET CONDITIONS
PRIMARY EXPLORATION
DEPLETION
discovery of mineral occurrences
ADVANCES IN TECHNOLOGY
DELINEATION
possible economic discoveries for evaluation
MINE DEVELOPMENT
CONSTRUCTION OF PROCESSING FACILITIES
MINING
PROCESSING
MINERAL SUPPLY
EXPLORATION
DEVELOPMENT
PRODUCTION

Figure 1. The Mineral Supply Process

pleted with what is perceived to be an economic mineral deposit as its end result.

Development, the second phase of the mineral supply process, establishes productive mining and mineral processing capacity. Since processing is required to upgrade the mine product to a metal concentrate or impure bullion that can be transported and sold, the construction of processing facilities is carried out in conjunction with mine development. A mill may be installed at the minesite, or a common processing facility may be used to treat ores from a number of mines in a region.

When a mine has been developed and related processing facilities have been constructed, the third phase - production - commences. The mining stage of production may include stripping waste for open pits, preparing stopes (underground excavations for mining), developing ore reserves, drilling, blasting, transporting materials to the processing facilities, filling mined-out stopes, and associated technical and planning services. For base metal operations, the processing stage of production usually includes crushing, grinding, flotation, drying, disposal of tailings, and the loading of concentrate products for shipment. Through processing, the ore produced from a base metal mine, which might contain 2 percent copper and 5 percent zinc, may be upgraded to produce a 25-percent copper concentrate and a 55-percent zinc concentrate, with the loss of 10 percent of the copper content and 20 percent of the zinc content in the tailings. For gold ores, processing typically comprises crushing, grinding, cyanidation, carbon-in-pulp adsorption, filtering, tailings disposal, and smelting. For example, a 6.5 gram per tonne gold ore may be treated to obtain a 98-percent gold bullion, with the loss of 6 percent of the gold content in the waste product.

The end result of the mineral supply process in the context of this study is the production of concentrate or bullion at the minesite to satisfy market demand. Market demand conditions include product transportation and smelting and refining activities as well as the sale of the metal.

The mineral supply process is dynamic in several respects. First, the market demand for mineral commodities changes with time. The factors that account for changing demand include: variations in the requirements of end uses; changes in the properties and relative costs of substitute materials; development of new product markets; and modifications in transportation, smelting, and refining conditions. Second, the physical exhaustion of mineral deposits, or depletion, is inherent in their exploitation. Thus, continual exploration is required just to sustain the existing level of mineral production. Furthermore, exploration, guided by geologic concepts and skills, is a systematic process in the long term, tending to detect first those deposits that are largest, of highest grade, closest to the surface, or closest to markets. Consequently, such deposits should, on average, be discovered, developed, and exhausted first, and deposits that are of lower grade, smaller, or harder to find come later. Thus, depletion causes the cost of mineral supply to rise over time. However, a third, offsetting dynamic force - advances in technology - is also at work. Such advances may include more efficient and extensive exploration techniques and improved mining and mineral-processing methods. This means, for example, that the best deposits are not necessarily found first, the Kidd Creek and Hemlo discoveries being notable Ontario examples. Advances in technology act to reduce the cost of mineral supply. The combined effect of these market, depletion, and technological forces determines the economics of mineral supply over time.

Potential Value of Mining

The potential value of mining is defined here as the difference between the revenue realized from mineral production and the costs required to realize those revenues, including an allowance for the cost of capital.[1] Since the cost of capital is deducted, this potential value represents the increase in real wealth to Canadian and Ontario society that results from investing in mining rather than in some other economic activity. Thus, potential value reflects both the quality of mineral resource endowment and the viability of the mining sector. It also measures the productive capability of mineral resources and represents what is available for sharing between industry and government before mining taxation and other public policy considerations.

---

[1]. The cost of capital is a real cost which affects the new wealth created by the mineral supply process.

Mineral Exploration Economics

As shown in figure 1, investment in the mineral supply process starts with the search for economic deposits. Thus, mineral exploration occupies the strategic up-front position in the supply process. At the beginning, all finding, development, and production activities represent controllable choices. This is the only time a mining company is not committed to particular programs, projects, or mines. It should not be surprising, therefore, that corporate exploration decisions are particularly sensitive to uncertainty and changes in government policy.

At the start of exploration, all costs, risks, and potential returns lie out in the future.[2] Decisions made at this point are obviously the most difficult to economically justify.

Investment in mineral exploration is not supportable as an end in itself. The economics of exploration are determined by the costs, risks, and returns of the three-phase mineral supply process described in the initial section of this chapter.

Economic mineral deposits are central to the mineral supply process. Consequently, the economics of exploration can be measured by the relationship between the exploration expenditures required to find and delineate an economic deposit, and the net return associated with its subsequent development and production.

In this study, mineral exploration economics is assessed both on a before-tax potential-value basis and on an after-tax basis. All direct costs and revenues associated with the exploration, development, and production phases of mineral supply are included.

The cost, risk, and return characteristics of mineral exploration are applied to measure the economic attractiveness of investment. Exploration investment criteria may be conveniently subdivided into long-term and short-term considerations. The long-term attractiveness of exploration is evaluated using various measures of expected value. The short-term problems associated with realizing expectations are assessed by risk criteria.

---

[2]. The premise here is that in the beginning an exploration organization has a complete range of choices. In practice, this might not be so. Small groups must constantly raise money, and large integrated companies like Noranda and Falconbridge have to support mines, mills, and smelters.

Expected Value Criteria

Expected value measures the average value that exploration yields in the long term, when the successes and failures associated with a very large (theoretically infinite) number of discoveries are considered. The expected value of exploration is derived from the time distribution of average cash flows for the discovery of an economic mineral deposit. This distribution is initially evaluated on a potential value basis as portrayed in figure 2. Then, to provide measures of investment incentive from the mining company's viewpoint and government revenues, the potential value assessment is converted to an after-tax basis as depicted in figure 3. The mining company decides on an after-tax basis whether it is worthwhile to invest in exploration. Because of time value considerations, the average cash flow characteristics must be brought to a common point in time or spread evenly over a common period of time to make a valid assessment. The following two measures of expected value are used in the present study.

1. Expected Value per Economic Discovery

An exploration expenditure E is required on average for the discovery and delineation of an economic deposit, yielding an average return R.

Thus:

$$EV = R - E$$

where EV = expected value per economic discovery;
R = average net return from development and production associated with the discovery of an economic mineral deposit;
E = average exploration cost required to find and delineate an economic deposit.

To make a valid comparison, R and E are expressed as discounted values at the start of the exploration phase, using a cost-of-capital estimate for investment funds as the discount rate.

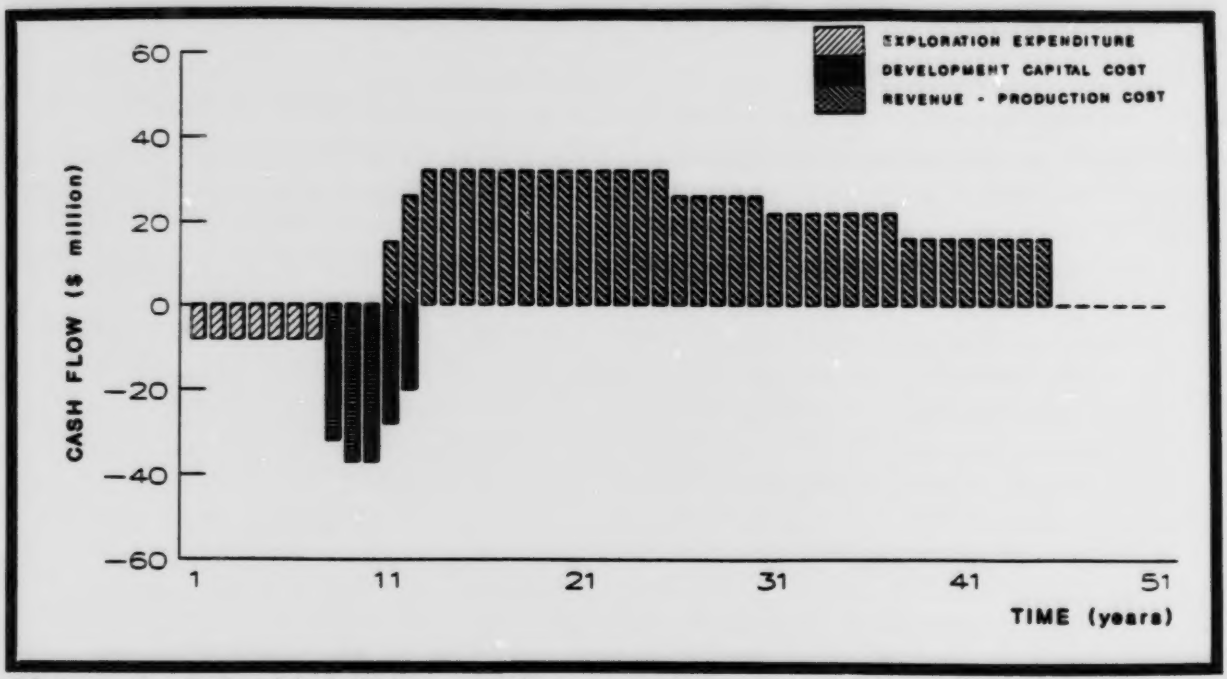


Figure 2. Potential Value of Mineral Exploration: Time Distribution of Average Cash Flows for an Economic Discovery

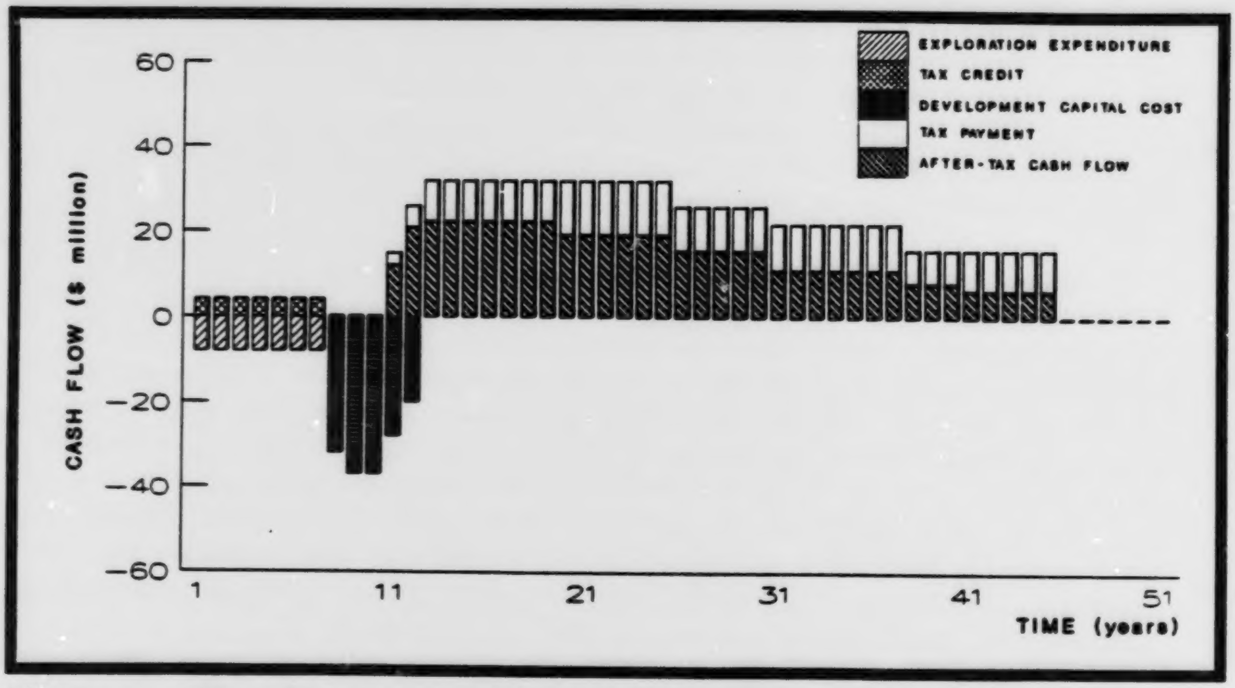


Figure 3. After-Tax Value of Mineral Exploration: Time Distribution of Average Cash Flows for an Economic Discovery

The higher the EV assessment, the more attractive exploration is perceived to be in the long term. Usually an expected value per economic discovery of greater than zero is regarded as a necessary condition for investment. A negative EV signifies that exploration is an unacceptable investment in the long term, with more money going "into the ground" in discounted terms than coming out.

The expected value per economic discovery is analogous to the criterion of net present value generally used in evaluation practice. As such, this measure reflects the intrinsic economic value of mineral exploration. Thus, EV comprises both size and profitability components.

2. Expected Rate of Return

The expected discounted cash flow rate of return on investment may also be evaluated based on the time distribution of average cash flows for an economic deposit depicted in figures 2 and 3. By definition, rate of return is the discount rate that equates the present value of the positive cash flows with the present value of the investment. In economic terms, rate of return is the average percentage annual return that exploration is estimated to yield over the life of the mineral supply cycle. Using this method, the minimum acceptable condition for exploration investment is an expected rate of return equal to the cost of capital.

Expected values are assessed in this study on the basis of overall exploration activity and reflect the average performance of all organizations that have undertaken exploration in Ontario. Obviously, there are benefits to be gained from the application of superior skills and selectivity in exploration. In exploration environments characterized by unacceptable overall expected values, the selection of opportunities of above-average merit is a necessary condition for long-term exploration success. This can only result from the application of superior exploration skills, developed within a mining company over time through continued exposure to particular environments of interest.

Risk Considerations

The four types of risk outlined below are associated with the realization of expected values in mineral exploration.

1. Market risk, reflecting the sensitivity of mining economics to the high level of uncertainty associated with forecasts of short-term fluctuations and long-term trends in mineral commodity prices, including exchange rate uncertainty.
2. Project risk, caused by the uncertainty associated with estimating ore reserves, recovery and dilution factors, capital expenditures, and operating costs for specific economic deposits.
3. Geologic risk, related to the uncertainty of the return, given an economic discovery, which arises because of the variability in size, grade, and other geologic parameters among economic deposits.
4. Discovery risk, the low probability - typically a 1 to 2 percent chance - of an economic mineral deposit, given the discovery of a mineral occurrence.[3] The implications of discovery risk for exploration planning is of particular importance.

These risks, individually and collectively, present challenges to the long-term profit, survival, and growth of organizations active in mineral exploration. Inevitably, actual results are very much different than those indicated on the basis of expected values. To be realistic, an understanding of these risks needs to be incorporated in the formulation of government mineral policy.

---

[3]. The discovery of a mineral occurrence, as portrayed in figure 1, is the successful outcome of primary exploration or, in other words, a technical or geologic success. More specifically, the discovery of a mineral occurrence can be defined as indications of mineralization of potentially economic grades across mineable widths obtained by drilling. Adopting this definition, empirical studies of mineral exploration in Canada and Australia show that there is typically a .01 to .02 probability of discovering an economic deposit each time a mineral occurrence is found.

The market risk arises from uncertainties in the materials market for mineral commodities. The economics of mineral supply is sensitive to anticipated prices. Flexibility is required in mineral policy and planning to contend with unexpected changes in market conditions. Thus, the assessment of base metal and gold exploration economics in Ontario made in the present study considers a wide range of possible long-term metal prices.

The project risk associated with the estimation of ore reserves, mining and processing costs for a particular mineral deposit is critical when an investment decision is being taken concerning mine development. However, when generalizing across many deposit situations to appraise the economics of mineral supply for broad regions of interest, as we are doing here, the individual project risks are not as important.

The geologic risk may be measured by cumulative probability distributions of return parameters such as total revenue, rate of return, and net present value for all economic discoveries. With reference to figure 4, cumulative probability distributions are constructed in the following manner. For each return parameter, individual deposit values are ordered from the lowest to the highest. These values are then plotted against cumulative probability, the fraction of the total number of economic deposits which have values less than or equal to each value. When the highest value is reached, the cumulative probability equals unity. Key statistics can then be derived as shown in figure 4 to represent the overall distribution. For example, a cumulative probability of 0.10 specifies the lower-decile value; i.e. 10 percent of the economic deposits have values less than or equal to the lower decile and 90 percent have higher values. The median (or middle) deposit value is designated by a 0.50 cumulative probability. The mean deposit value is the average of all deposit values. The distribution of returns around the mean value is the economic reflection of the geologic variability which exists among economic deposits.

Because the discovery risk is so high, the application of limited exploration funds does not ensure the realization of expected values. Thus, exploration resources are often expended without success. The organizational risk associated with exploration success can be quantified by applying the classical problem of the gambler's ruin. The practical implication of discovery risk for a mining company is that there is a large difference between

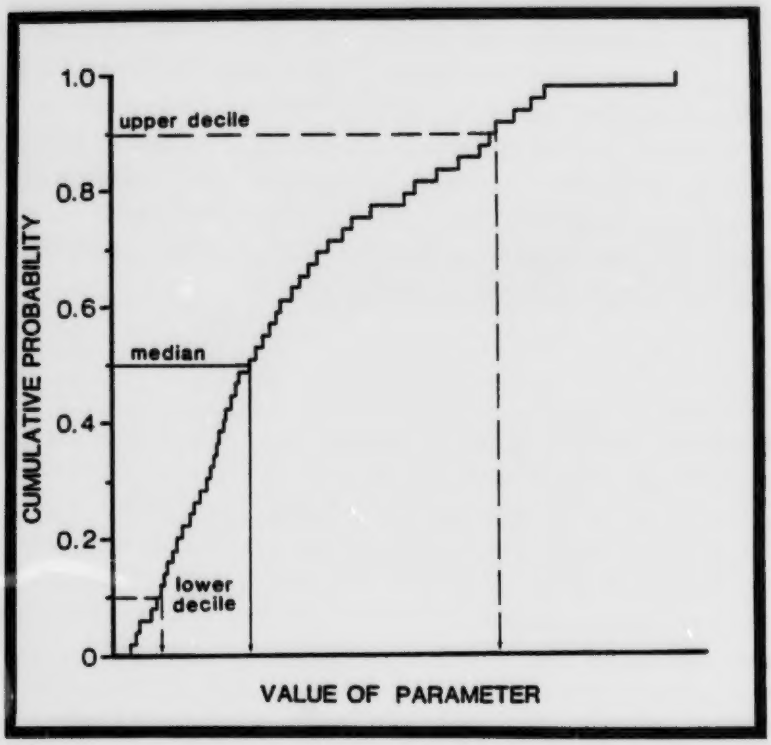


Figure 4. Cumulative Probability Distribution and Key Statistics of a Return Parameter for Economic Deposits

the average exploration cost required to find and delineate an economic deposit and the exploration funds required to ensure success. For example, the exploration funds required to be 90 percent sure of finding at least one economic deposit are more than 2-times greater than the average exploration cost associated with an economic discovery.

Mine Development Economics

Mine development represents the medium-term view of the economics of the mineral supply process. The exploration phase investment is at this point a sunk cost. The discovery and geologic risks have both been resolved. One particular economic deposit, found and delineated, now awaits development.

The development of an economic deposit is the result of successful exploration. Because exploration time and cost have been expended in resolving risks to arrive at this favourable outcome, the economics of mine development, as we will see, are typically much more attractive than the economics of mineral exploration. Since the commitment of a large investment in productive capacity is being considered at this point, development decisions are also sensitive to government policy.

Expected Value Criteria

The expected value of mine development measures the average revenues and costs of the development and production phases of the mineral supply process. To obtain a representative general picture of mine development economics, cash flow estimates can be averaged across all economic deposits discovered. The time distribution of average cash flows for an economic mineral deposit is illustrated in figure 5 on a potential value basis and after tax in figure 6. These cash flow distributions, it should be noted, are identical to the development and production phase values depicted in figures 2 and 3.

Each time a mine development decision is taken, however, it is the cash flow profile of the particular deposit being considered, not the general representations shown in figures 5 and 6, that is relevant. The variability in cash flow characteristics among economic deposits should therefore be an important factor to examine when considering the economics of mine development for government policy purposes.

In a comparable way to that outlined for mineral exploration, discounted cash flow methods are applied to summarize the cash flow estimates in terms of expected value criteria. Once again, two measures of expected value have been selected for use in the study.

1. Expected Net Present Value

   The expected net present value converts the anticipated time distribution of cash flows for a mine development project into an equivalent dollar value at the start of development. To do this, each cash flow is discounted to this point using the cost of capital rate. The present value components are then summed to yield the expected net present value. Thus, net present value is the difference between the discounted posi-

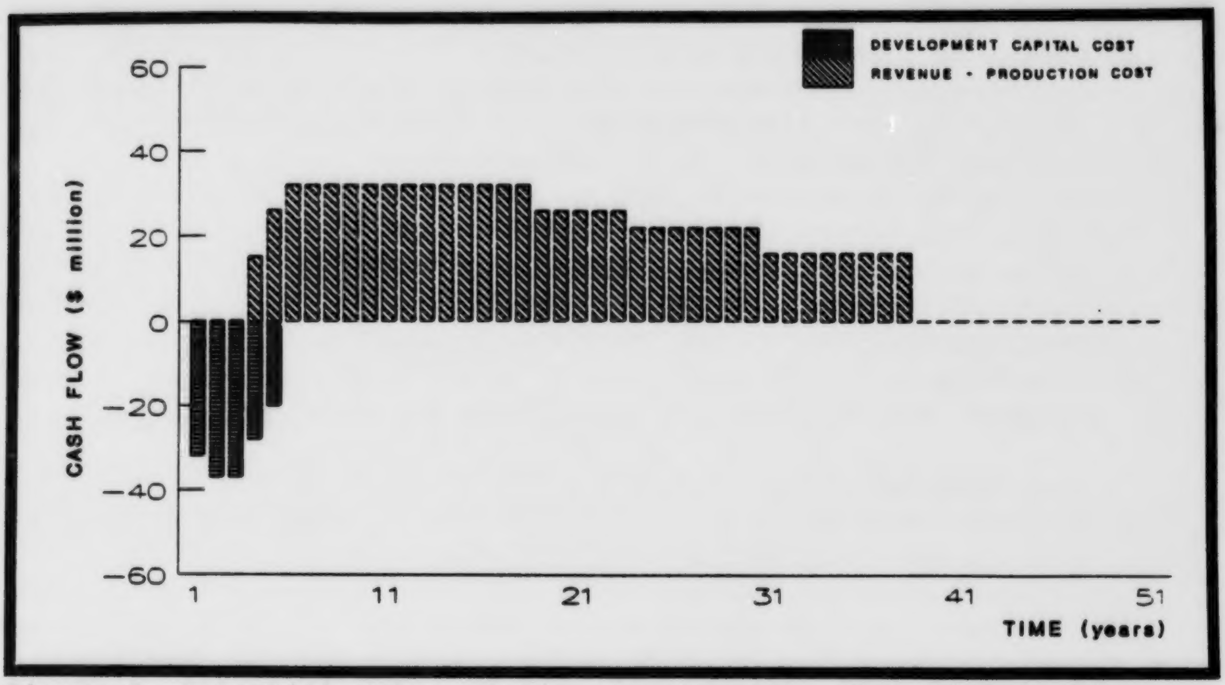


Figure 5. Potential Value of Mine Development: Time Distribution of Average Cash Flows for an Economic Mineral Deposit

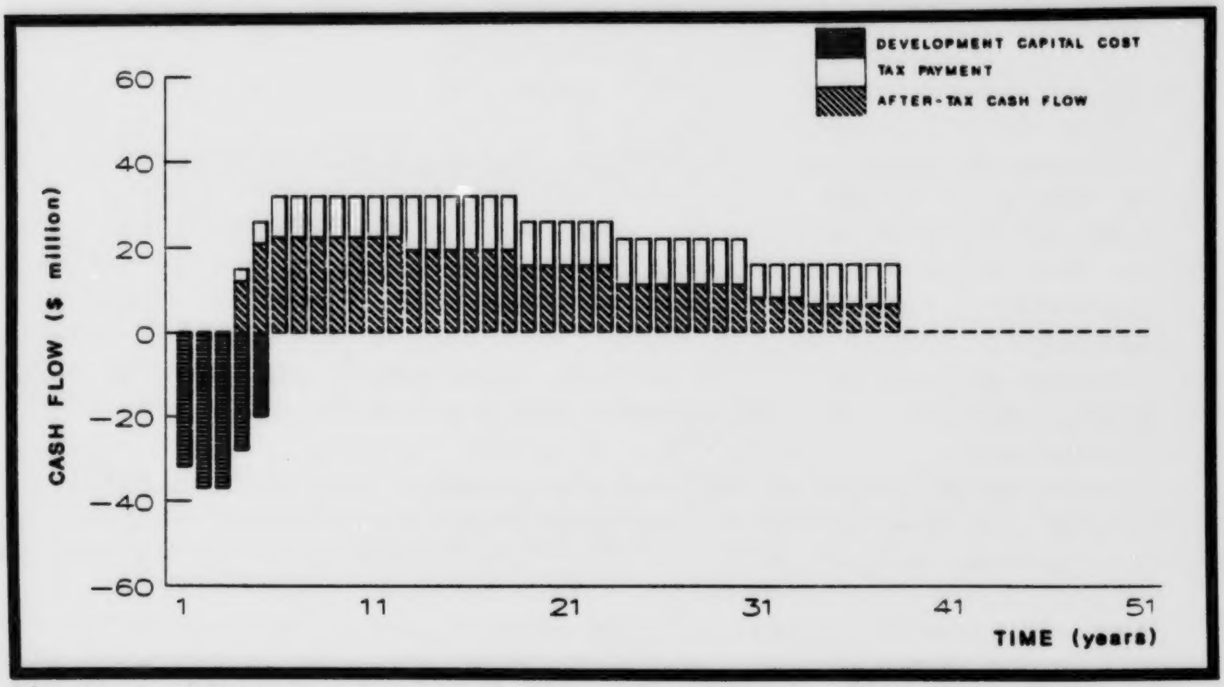


Figure 6. After-Tax Value of Mine Development: Time Distribution of Average Cash Flows for an Economic Mineral Deposit

tive cash flows from production and the discounted development-phase investment. Using this criterion, the minimum acceptable condition for investment in mine development is an expected net present value equal to zero.

With reference to the exploration criteria previously discussed, the expected net present value is directly related to R, the difference being that R is expressed as a discounted value at the start of exploration rather than at the start of development.

2. Expected Rate of Return

The expected rate of return for mine development is the discount rate which equates the present value of the positive cash flows from production with the present value of the development-phase investment. In other words, the expected rate of return is the discount rate which gives a zero net present value. Using this criterion, the minimum acceptable condition for investment in mine development is an expected rate of return equal to the cost of capital.

Risk Considerations

The discovery risk and the geologic risk risk previously outlined are resolved in the exploration phase prior to appraising the economics of mine development. One particular economic deposit is now available for mine development, sampled by a successful exploration program from the total population of economic deposits awaiting discovery. The cash flow profile and the economic criteria associated with the mine development opportunity are determined in part by the geologic characteristics which have been delineated.

The market risk associated with mine development is similar to that associated with mineral exploration. Because potential mine production is closer at hand, more reliable price projections may be possible but, typically, a high level of market uncertainty will remain until it is resolved year by year in the course of production. The project risk associated with the estimation of ore reserves, capital expenditures, and operating costs is also of critical importance to evaluation and decision making at the development decision point. These market and project risks can be evaluated using sensitivity analysis and, more comprehensively, by applying probabilistic risk analysis methods.

In the present study, market risk is examined using sensitivity analysis. No attempt is made to measure project risk. The broad comparative nature of the study, assessing the economics of many potential mine development opportunities, makes this impractical. In any case, we are not faced with taking a capital intensive mine development decision for a particular deposit. Rather, we are trying to create a more general appreciation of mine development economics for government policy purposes.

Evaluation Procedure

The economic potential of mineral exploration and mine development are determined by the costs and revenues of the exploration, development, and production phases of the mineral supply process. The focal point of this process is economic mineral deposits. Consequently, potential value measures are derived from estimates of the exploration expenditures, development costs, and operating revenues and costs associated with an economic deposit.

In the evaluation procedure described here, the potential value of mining is appraised on the basis of historical experience. Two assumptions are necessary if the results are used to plan for the future. First, deposits yet to be found must resemble, in economic terms, those that have been found to date. Second, the cost of making a future discovery must be similar to the cost in the past. However, since the mineral supply process is dynamic, we should certainly endeavour to discern time trends within the overall historical experience.

The data base for assessing the potential value of an economic deposit comprises the documentation of actual exploration, development, and production experience over a relevant historical timeframe - the 1946-85 period is selected for example in the appraisal of base metal and gold exploration and development potential in Ontario introduced in chapter 3. For policy and planning purposes, this information is then evaluated in the context of current outlook conditions.

In essence, the methodology (diagrammed in figure 7) follows these steps.

1. Total exploration expenditures are estimated for the historical time period of interest.
2. Significant deposits discovered as a result of these expenditures are classified by discovery date and listed for evaluation.
3. The cash flow characteristics of the development and production phases for each of these possible economic discoveries are evaluated on the basis of current outlook conditions.
4. Discoveries that on evaluation satisfy minimum conditions of size and profitability are designated as economic deposits.
5. Cash flow characteristics of the development and production phases for all economic deposits are analyzed to depict the economics of mine development and then are averaged.
6. Total exploration expenditures, which cannot in general be directly associated with the economic discoveries, are prorated across all economic deposits evaluated.
7. Estimates for the exploration phase are integrated with the average characteristics for the development and production phases to portray the time distribution of average costs and revenues for an economic deposit from the start of exploration to the end of production.
8. Several expected value criteria and risk measures, earlier described are derived from the assessment. These indicators reflect the potential value of mineral exploration.

More specifically, the development and production phase characteristics for each of the possible economic discoveries (step 2 above) are evaluated (step 3), as shown in figure 7, by combining general market estimates of metal prices and smelter payments with estimates for individual deposits of the following: recoverable ore reserves; mill recovery factors; a stripping ratio for open pits; mine and mill capacities; capital costs, including the working capital requirement; the length of the preproduction development period; and operating costs. These estimates, based on the actual historical record, attempt to portray how each deposit would look today if it was awaiting development. A number of measures of economic worth are derived from the resulting cash flow distributions, including the total sales revenue generated and the rate of

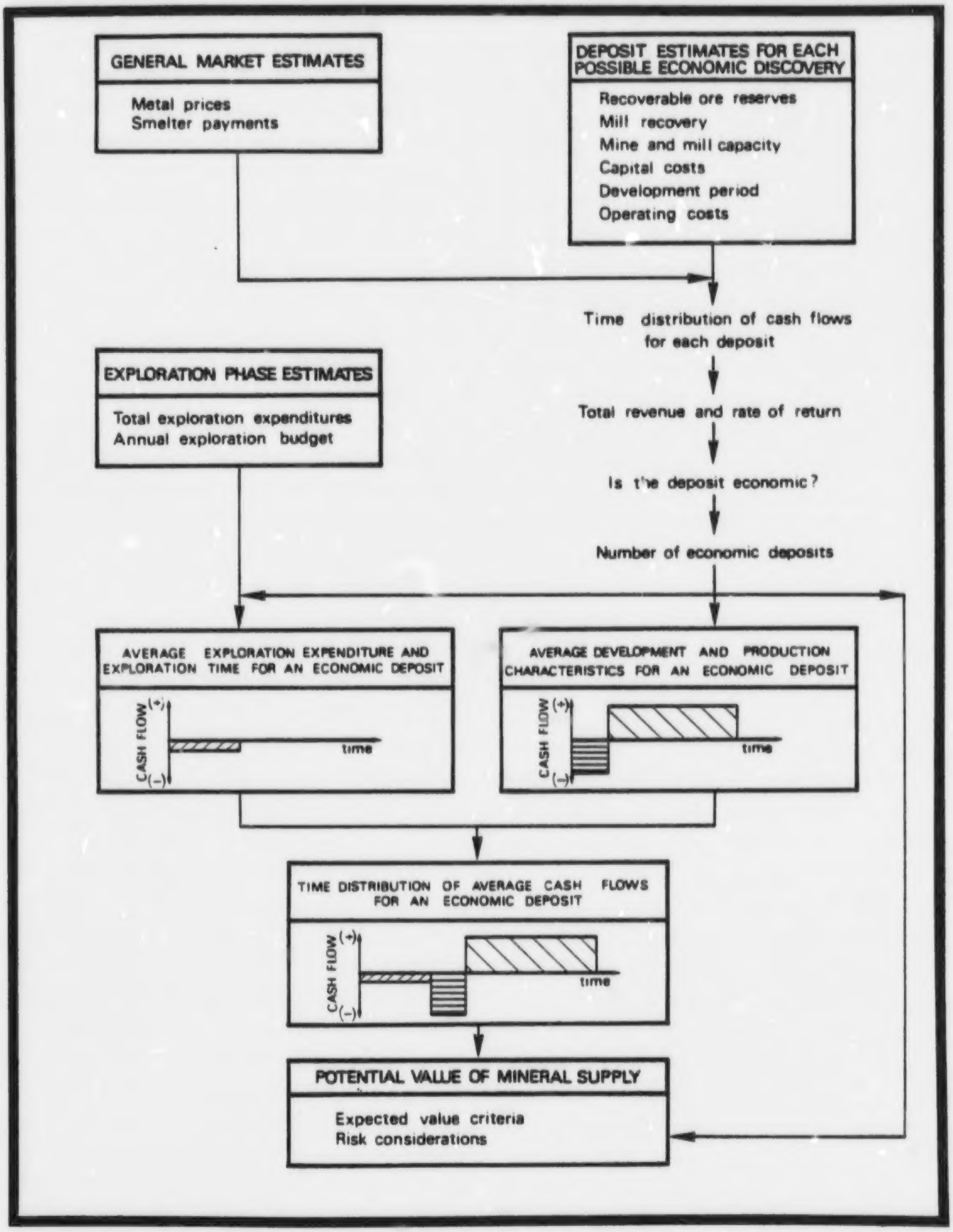

GENERAL MARKET ESTIMATES
Metal prices
Smelter payments
DEPOSIT ESTIMATES FOR EACH POSSIBLE ECONOMIC DISCOVERY
Recoverable ore reserves
Mill recovery
Mine and mill capacity
Capital costs
Development period
Operating costs
Time distribution of cash flows for each deposit
Total revenue and rate of return
Is the deposit economic?
Number of economic deposits
EXPLORATION PHASE ESTIMATES
Total exploration expenditures
Annual exploration budget
AVERAGE EXPLORATION EXPENDITURE AND EXPLORATION TIME FOR AN ECONOMIC DEPOSIT
AVERAGE DEVELOPMENT AND PRODUCTION CHARACTERISTICS FOR AN ECONOMIC DEPOSIT
TIME DISTRIBUTION OF AVERAGE CASH FLOWS FOR AN ECONOMIC DEPOSIT
CASH FLOW
(+)
(−)
time
POTENTIAL VALUE OF MINERAL SUPPLY
Expected value criteria
Risk considerations

Figure 7. Procedure for Evaluating the Potential Value of Mineral Supply

return. Those discoveries that satisfy minimum conditions for total revenue (size) and rate of return (profitability) are deemed to be economic (step 4). The return characteristics of the economic deposits are analyzed to portray the economics of mine development. The cash flow estimates for all economic deposits are then averaged (step 5), resulting in a time distribution of average cash flows for the development and production phases of the mineral supply process.

With respect to appraisal of the exploration phase (step 6), the total exploration expenditure estimate (step 1) is divided by the number of economic deposits assessed (step 4) to determine the average exploration expenditure required to find and delineate an economic deposit. To evaluate the average exploration time that would be needed to make an economic discovery, the average exploration expenditure per economic discovery is divided by an assumed most-efficient annual exploration budget, rate. These estimates for the exploration phase are then integrated with the appraisals for the development and production phases.

As portrayed in figure 7, the end result of this evaluation process is an assessment of the time distribution of average cash flows for an economic deposit over the entire mineral supply process (step 7). The expected value and risk measures which are derived from these estimates to portray the before-tax, potential value characteristics of base metal and gold exploration in Ontario (step 8) have been outlined in previous sections. As part of the evaluation, the sensitivity of results to key study assumptions is examined.

Summing Up

Appraisals of the potential value of the mineral supply process are derived from estimates of the exploration expenditures, development costs, and operating revenues and costs associated with an economic deposit. The evaluation procedure adopted mixes historical discoveries and developments with future prices to arrive at a "present day" appraisal of these discoveries. This provides an objective basis for assessing and comparing the economic potential of base metal and gold exploration and development in Ontario.

3. BASE METAL AND GOLD EXPLORATION AND DEVELOPMENT IN ONTARIO, THE SHIELD REGION, AND CANADA: THE DATA BASE

Study Specifications

The assessments of mineral exploration and mine development provided in this study are based on the 40-year period 1946-85. This time period is subdivided into four decades - 1946-55, 1956-65, 1966-75, and 1976-85 - to examine time trends in exploration and development characteristics.

Money values unless otherwise specified are expressed in constant 1987 Canadian dollars. Discount rates and costs of capital are therefore expressed as real rather than nominal rates. Inflation is taken into account to correctly assess tax allowances and payments.

Trends in historical current-dollar statistics that are purely inflationary are removed by applying the Gross Domestic Product (GDP) Implicit Price Index. This aggregate price index provides a good approximation of the economy-wide rate of inflation. The GDP Implicit Price Index and the inflation multiplier series derived from it to convert historical data to 1987-dollar equivalents are shown in appendix I.

One aspect of our evaluation is to determine which of the mineral deposits discovered in the past would be economic under today's conditions. An economic deposit is defined as a discovery that realizes a total revenue of at least $20 million and a rate of return of at least 8 percent. The $20 million minimum size ensures that any deposit of significance is included in the evaluation. The 8-percent rate-of-return investment margin has been selected as a best estimate of the weighted average cost of capital for mineral investment funds. The effects of profitability thresholds of 5 percent and 12 percent on exploration and development potential are also examined.

Total Exploration Expenditures

Estimates of total exploration expenditures are required for each commodity grouping, geographic region, and time interval of interest. The intention is to include all costs associated with searching for and delineating the possible economic discoveries of interest. Unsuccessful exploration expenditures are of course the main component of these costs. Total exploration expenditures are difficult to estimate, mainly because government statistics are too aggregated to be directly applicable.

The approach used to estimate mineral exploration expenditures for study purposes is described in appendix II. A large number of sources are utilized in deriving the final study series. Statistics and subjective judgments have been obtained from federal and provincial government departments as well as from exploration personnel in mining companies.

As in earlier CRS studies, Dominion Bureau of Statistics' series on the cost of prospecting have been used extensively for the 1946-63 period.[4] For the remainder of the study period, Statistics Canada data for both on-property and off-property exploration expenditures are the primary source. Only off-property expenditures were included in earlier CRS studies. There are several reasons for now including on-property expenditures:

- a substantial amount of primary exploration for new deposits is carried out on existing mining leases;
- our evaluation of development potential is based on the most complete ore reserve estimates available;
- on-property exploration is a valid activity to be included in total exploration for evaluation purposes.

More data from provincial government sources have been used in the present study than in the past. Statistics Canada expenditures have been augmented in some years to reflect more comprehensive provincial totals.

Base metal exploration expenditures are derived as a residual by deducting expenditures for all other metals from a total metallic mineral exploration series. Series for other metals - including nickel, uranium, and iron ore - based on more reliable data, have been constructed in more detail than in earlier studies. As a result, the residual base metal series derived in appendix II should also be more dependable and complete. Gold exploration expenditure estimates are similar to the series assembled for a recent CRS project.[5] The present series however includes better figures for 1985. Some adjustments have also been made to the totals for earlier years based on new information and refinements in our estimating procedure.

---

[4] For a description of the method of estimation and sources of data used for base metal exploration expenditures in earlier CRS studies, see appendix II, Effects of Taxation on Base Metal Mining in Canada, B.W. Mackenzie and M.L. Bilodeau, Centre for Resource Studies, Queen's University, 1979.

The resulting series of exploration expenditures are presented in appendix II. Table 1 summarizes these expenditures by commodity grouping and time interval for Ontario, the shield region, and Canada. Exploration expenditures in Ontario total approximately $1.4 billion for the study period, split almost evenly between base metals (51 percent) and gold (49 percent). Ontario is shown to account for 34 percent of exploration activity in the shield region and 19 percent of Canada-wide expenditures during the study period.

Annual Exploration Budget Rate

An assumption is required concerning the annual exploration budget of a mining company as part of the determination of the average exploration time that would be needed to discover an economic deposit.

Based on discussions with exploration personnel and on observations of both successful and unsuccessful exploration at work, a $6.0-million annual exploration budget has been chosen as an efficient level for an exploration organization. While opinions on this subject vary and the $6.0 million figure may be debated, there can be little doubt that the most efficient budget rate lies within the range of $3.0 to $9.0 million per year.

---

[5]. See "Long-Term Breakeven Price for Canadian Gold Supply", D. Cranstone, B. Mackenzie, and M. Doggett, in Long-Term Prospects for Gold Mining, edited by B. Mackenzie and R. Gesing, Centre for Resource Studies, Queen's University, 1987.

Table 1

TOTAL BASE METAL AND GOLD EXPLORATION EXPENDITURES
(millions of constant 1987 Canadian dollars)

Commodity Grouping and Time Interval	Ontario	Shield Region	Canada
Base Metals:			
1946-55	31	91	226
1956-65	149	625	1,061
1966-75	257	824	2,165
1976-85	305	920	1,812
1946-85	742	2,460	5,264
Gold:			
1946-55	62	158	190
1956-65	56	140	172
1966-75	100	209	295
1976-85	489	1,247	1,740
1946-85	707	1,754	2,397
Base Metals and Gold:			
1946-55	93	249	416
1956-65	205	765	1,233
1966-75	357	1,033	2,460
1976-85	794	2,167	3,552
1946-85	1,449	4,214	7,661

The $6.0-million budget is considered large enough to afford the best possible exploration skills and techniques, and small enough to encourage a high degree of motivation and organizational efficiency. Assessments are also carried out for annual exploration budgets of $3.0 million and $9.0 million. Total exploration expenditures are not changed by these budget rate variants. All that is affected is the estimated average time required for an exploration organization to discover an economic deposit.

Possible Economic Discoveries for Evaluation

In Ontario, 82 base metal and gold discoveries that could possibly satisfy our "economic deposit" definition are selected for evaluation. The Ontario discoveries are part of 297 possible economic deposits in the shield region and 539 discoveries in the Canada-wide data base. These deposits are listed in alphabetical order in appendix III, classified by commodity grouping, geographic region, and discovery date.

A discovery is considered to have been made when the deposit that ultimately forms the basis for mine development was first encountered, usually by drilling. Deposits are treated individually if their discovery required essentially independent primary exploration programs. The intention is to include all known deposits of at least 200,000 tonnes that offer medium-term potential for development. A few exceptions are made below this size threshold for deposits of exceptionally high grade. A listing of other deposits considered but not included in our evaluation is given in appendix IV with reasons for their exclusion.

The distribution of possible economic discoveries in Ontario, the shield region, and Canada is summarized in table 2. The 70 significant discoveries made in Ontario during the 1946-85 period are, like the associated exploration expenditures, almost evenly split between base metal deposits (34) and gold deposits (36). Ontario is shown to account for 28 percent of the deposits discovered during the study period in the shield region and for 16 percent of the discoveries made in Canada.

While the base metal deposits discovered prior to 1946 - 12 in Ontario, 43 in the shield region, and 102 in Canada - cannot be included in the overall analysis of exploration economics, they help provide a more complete picture of mineral endowment characteristics, the time trend of returns from economic discoveries, and mine development potential.

Table 2

NUMBER OF POSSIBLE ECONOMIC DEPOSITS FOR EVALUATION

Commodity Grouping and Discovery Date	Ontario	Shield Region	Canada
Base Metals:			
Pre-1946	12	43	102
1946-55	13	37	61
1956-65	10	43	92
1966-75	8	45	103
1976-85	3	24	47
1946-85	34	149	303
Total	46	192	405
Gold:			
1946-55	5	14	15
1956-65	5	20	21
1966-75	4	9	13
1976-85	22	62	85
1946-85	36	105	134
Base Metals and Gold:			
1946-55	18	51	76
1956-65	15	63	113
1966-75	12	54	116
1976-85	25	86	132
1946-85	70	254	437

Note: the pre-1946 base metal discoveries are included in the base metals "total".

General Market Estimates

General market estimates are made to evaluate the time distribution of revenues for each of the possible economic discoveries. Since metal price is both the most important and the most uncertain variable in the assessment of cash flows, cash flows are evaluated as a function of price. An expected or mean price outlook is bounded by upper- and lower-limit prices for each mineral commodity. The prices used are shown in table 3. These are long-term average price estimates, the period of which is intended to correspond to the time frame of the three-phase mineral supply process being evaluated.

The assessment of costs and revenues assumes that concentrate or bullion is produced at each possible mine. General net smelter return conditions for copper, lead, and zinc concentrates are used to convert the forecast metal prices to a revenue estimate for the sale of concentrate at the smelter. Concentrate transportation costs are then deducted to work the smelter payment back to a minesite value. In the case of gold deposits, all-inclusive marketing charges are levied for impure bullion and gold concentrate products. The smelter return conditions, concentrate transportation costs, and gold marketing charges used in the study are given in appendix V.

Estimates for Individual Deposits

Deposit-specific estimates of recoverable ore reserves, mine and mill capacities, preproduction period, preproduction capital cost including the working capital requirement, the cost of major modifications, sustaining capital, operating cost, mill recovery factors, concentrate grades, and concentrate transportation, are calculated for each of the 539 possible economic discoveries, based on present-day economic and technological conditions. These deposit estimates utilize actual historical data and feasibility study estimates to the extent available. Otherwise, general Canadian costing relationships are applied, reflecting an order-of-magnitude level of accuracy.[6]

---

[6]. A new set of deposit costing relationships has been developed for study purposes with the assistance of T.A. O'Hara. Evaluation procedures based on these relation-

Table 3

LONG-TERM PRICE VARIANTS FOR MINERAL COMMODITIES
(1987 United States dollars)

		Price Variants		
Metal	Price Basis	Lower-Limit	Expected	Upper-Limit
Cadmium	pound	2.00	3.00	4.00
Copper	pound	0.80	1.00	1.25
Gold	ounce	250	400	500
Iron[7]	mtu in concentrate	0.18	0.22	0.25
Lead	pound	0.30	0.35	0.45
Molybdenum	pound in concentrate	2.50	3.50	5.00
Silver	ounce	4.00	6.00	9.00
Zinc	pound	0.35	0.45	0.50
Exchange Rate	US$/C$	0.80	0.65	0.55

mtu: metric tonne unit

---

ships are outlined here and in appendix V. It has not however been possible to fully implement the new system in this study. The results presented in chapter 4-7 are therefore also partially based on indexing deposit costing relationships developed in the early 1980s.

[7]. The iron ore concentrate prices are used to evaluate the Tasu copper-iron ore deposit in British Columbia, considered as a base metal deposit for study purposes.

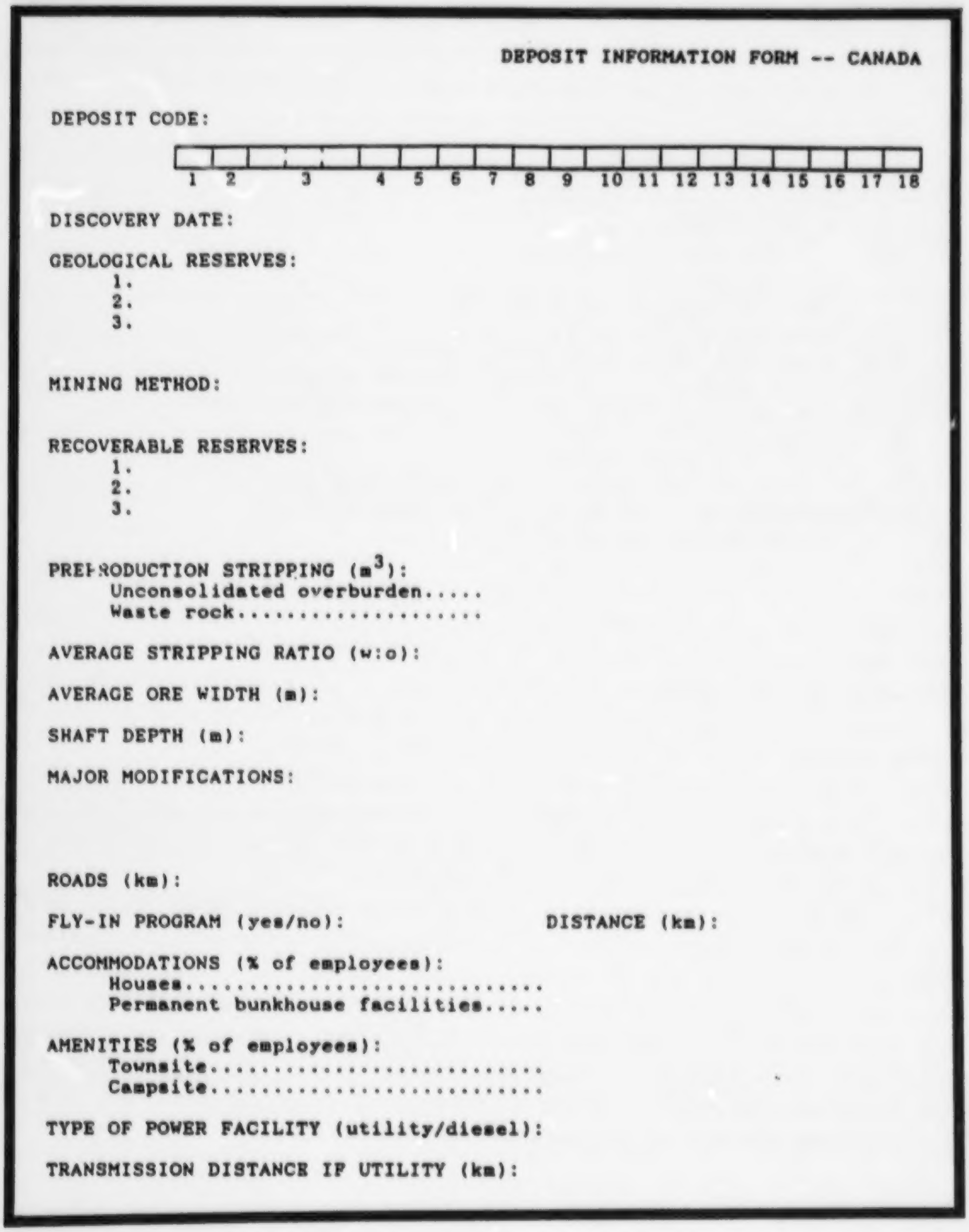
The form in which the basic estimates are provided for each deposit is shown in figure 8. The coding scheme maintains the anonymity of the deposits and facilitates their classification for analysis. Coding specifies the following characteristics of the deposit.

1	exploration environment
2	province or territory
3	deposit code
4,5,6	geological classifications
7	mining method
8	underground stoping method
9	general surface services
10	mine and mill site preparation
11	host rock conditions for shaft sinking
12	ground conditions for concrete foundations
13	temperature conditions
14	grinding conditions
15,16	ore type for mineral processing
17	conditions for tailings storage
18	investment tax credit

The first sheet of deposit estimates (figure 8) and the top of the second sheet (to the dotted line) itemize the information which must be specified to evaluate a deposit on the basis of the order-of-magnitude costing relationships. Estimates based on actual deposit data and feasibility study projections are entered below the dotted line on the second sheet.

The general deposit costing relationships used in the appraisal when actual data or specific estimates are not available, provide an order-of-magnitude (±30 percent) level of accuracy. These relationships are outlined in appendix V.

With respect to processing facilities, where more than one deposit of the same type exists in a region, deposits are evaluated assuming utilization of a common mill facility. The overall regional mill capacity is specified, as is the distance between the deposit and the mill. The deposit is allocated a proportion of the mill capital cost based on relative capacities. The distance is used to estimate a road-haulage transportation cost for the ore. Additional road construction may be specified.



DEPOSIT INFORMATION FORM -- CANADA

DEPOSIT CODE:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

DISCOVERY DATE:

GEOLOGICAL RESERVES:
1.
2.
3.

MINING METHOD:

RECOVERABLE RESERVES:
1.
2.
3.

PREPRODUCTION STRIPPING (m^3):
Unconsolidated overburden.....
Waste rock....................

AVERAGE STRIPPING RATIO (w:o):

AVERAGE ORE WIDTH (m):

SHAFT DEPTH (m):

MAJOR MODIFICATIONS:

ROADS (km):

FLY-IN PROGRAM (yes/no): DISTANCE (km):

ACCOMMODATIONS (% of employees):
Houses............................
Permanent bunkhouse facilities.....

AMENITIES (% of employees):
Townsite..........................
Campsite..........................

TYPE OF POWER FACILITY (utility/diesel):

TRANSMISSION DISTANCE IF UTILITY (km):

Figure 8. Deposit Estimate Form

REGIONAL MILL ALTERNATIVE:
Capacity (tonnes per year).........
Ore transport distance (km)........
Roads required (km)................

CONCENTRATE TRANSPORTATION:

Commodity ________ ________ ________ ________
Destination
Road distance (km)
Rail distance (km)
Ocean route

ACTUAL INFORMATION

ORE CAPACITY (tonnes per year):

MINE RECOVERY (%):

MINE DILUTION (%):

AVERAGE ORE WIDTH (m):

PREPRODUCTION PERIOD (years):

PREPRODUCTION CAPITAL COSTS ($ million or % change):

Mine development
Mine plant and equipment
Mill facilities
Infrastructure
Working capital

Total

Infrastructure Breakdown
Roads
Housing
Townsite
Power

Total

OPERATING COSTS ($ per tonne of ore or % change):

Mining
Milling
Overheads

Total

METALLURGICAL RECOVERIES (%):

CONCENTRATE GRADES (%):

REGIONAL MILL ALTERNATIVE:
Capital cost ($ million)................
Operating cost ($ per tonne of ore).....

Figure 8. Deposit Estimate Form (continued)

Table 4 presents average mine development parameters for all deposits in the study data base. These statistics may be viewed as providing representative deposit profiles. The following points of interest arise from these results:

- base metal deposits in Ontario are large on average relative to other base metal deposits in the shield region, primarily because of the influence of the Kidd Creek and Geco orebodies;
- base metal deposits in Ontario are small on average relative to other base metal deposits in Canada, primarily because of the occurrence of very large porphyry deposits in British Columbia;
- as measured by recoverable ore reserves, base metal deposits are much larger on average than gold deposits;
- the average size of gold deposits in Ontario is somewhat larger than elsewhere in Canada due to the presence of the Hemlo orebody;
- revenue per tonne provides a measure of recoverable, payable ore grade. Based on this indicator and the expected metal prices assumed in table 4, the average grade of gold deposits is found to be about twice as high as the average grade of base metal deposits;
- the total revenue potential of base metal deposits is shown to be significantly greater on average than for gold deposits. In this respect, the larger recoverable ore reserves for base metal deposits more than offset their relatively low grades (unit revenue);
- productive mine lives average between 8 and 11 years for the commodity groupings and regions considered;
- direct relationships are shown to exist between several of the mine development parameters. Annual mill capacity is obviously a function of the size of ore reserves. Preproduction capital cost is determined in part by the required capacity. Unit production costs are partially a function of the scale of operation (capacity), depending as well on the mining method (particularly on whether the deposit is mined as an open pit or underground operation).

Table 4

AVERAGE MINE DEVELOPMENT PARAMETERS FOR BASE METAL AND GOLD DEPOSITS

Commodity Grouping and Region	Possible Economic Discoveries (number)	Recoverable Ore Reserves (t mill.)	Annual Mill Capacity (t thou.)	Productive Mine Life (years)	Preproduction Capital Cost ($ mill.)	Unit Production Costs ($/t)	Unit Revenue ($/t)	Total Revenue ($ mill.)
Base Metals:								
Ontario	46	7	285	10	37	83	67	542
Shield Region	191	5	294	10	45	97	75	391
Canada	405	25	1,120	11	74	77	77	635
Gold:								
Ontario	36	4	231	8	42	66	151	478
Shield Region	105	3	236	9	35	64	142	352
Canada	134	3	245	9	34	67	149	332
Base Metals and Gold:								
Ontario	82	5	261	9	39	76	104	514
Shield Region	296	4	274	9	41	85	99	377
Canada	539	19	902	11	64	75	95	560

Note: the unit and total revenue estimates are based on expected metal prices and evaluated at the minesite.

Critique of the Data Base

The information utilized for this study has been assembled on a continuing basis since 1972. Nevertheless, there are a number of data base limitations.

First, possible economic deposits are classified on the basis of their discovery dates. As there is an uncertain time lag between the start of exploration and the discovery of a deposit, it is possible that exploration expenditures included in the economic assessment for one time interval, may result in discoveries included in the following time interval, or vice versa. Since we are examining four 10-year intervals, this discrepancy should not significantly alter time trends. It may be important however if, as a result, possible economic deposits are excluded from the overall time period. For this reason, three discoveries made early in 1986 have been included in the evaluation. The 40-year period chosen is considered to be of sufficient duration to minimize these spillover effects.

Second, the data base for older mines tends to be more complete than that for the more recent discoveries. This is especially important with respect to ore reserve estimates, since development and production typically proceed on the basis of partial delineation results. Our objective has been to include as complete an estimate as possible for the tonnage and grade characteristics of each deposit. There is nevertheless an inevitable tendency to undervalue the appraisals, especially for deposits discovered in the most recent time interval. The possible undervaluation is particularly significant with respect to ore reserve tonnage. This problem can be eased only by periodic updating and improvement of the data base.

It can be argued that the use of historical exploration expenditures results in overestimating the exploration costs that would be required under today's conditions. This contention is based on the increasing effectiveness of exploration. Thus, it would presently require lower exploration expenditures to find the deposits which were discovered historically. However, as discussed in chapter 2, both depletion effects and advances in technology act over time, leading to either an increase or a decrease in finding costs, depending on their resultant. In this study, these effects are examined by studying time trends within the overall 40-year study period. Otherwise, it is reasoned that the cost of making a future discovery will be similar to the cost in the past.

These and other shortcomings in the data base reflect a compromise between the availability of data and the research limitations imposed by time constraints. While there is certainly room for improvement, it is suggested that the existing data base is sufficient to support a useful and meaningful appraisal of mineral exploration and mine development potential in Ontario.

Data Processing

The data base is processed by computer programs developed for the Centre for Resource Studies by Professor Michel Bilodeau, Department of Mining and Metallurgical Engineering, McGill University. There are three separate procedures which are named MINDEC 1, MINDEC 2 and MINDEC 3.

MINDEC 1 is a program that computes the development and production characteristics of each possible deposit. The MINDEC 2 program then retrieves the cash flow elements and economic characteristics of the economic mineral deposits, computes their averages, lists the unit development and production components of cash flow for an economic deposit, and plots cumulative probability distributions. MINDEC 3 is a program to retrieve the yearly cash flow elements of economic mineral deposits. It then computes the time distribution of average cash flows for an economic deposit and associated economic characteristics with and without the average exploration period cash flows.

Variants for Analysis

To summarize, our evaluation of mineral exploration and mine development potential includes the following variants.

- potential value of mineral exploration in Ontario
    - base metals and gold together
    - base metals and gold compared
- potential value of mine development in Ontario
    - base metals and gold together
    - base metals and gold compared

- sensitivity of mineral exploration and mine development potential to key study parameters
  - metal price variants
  - annual exploration budget variants
  - cost of capital variants
  - effect of the Kidd Creek and Hemlo deposits
- Ontario's competitive position in the shield region and in Canada
  - mineral exploration potential
  - mine development potential
  - metal price variants
  - time trends

4. POTENTIAL VALUE OF MINERAL EXPLORATION AND MINE DEVELOPMENT IN ONTARIO

Mineral Exploration Economics

Base Case Results

The base case conditions which are used as a standard of comparison with other results, are:

- 70 possible economic base metal and gold deposits discovered in Ontario during the 1946-85 period;
- expected metal price conditions;
- 8-percent cost of capital and minimum acceptable rate of return for an economic deposit;
- $6-million annual exploration budget.

Under these conditions, 39 of the 70 deposits are found to be economic. The cost and revenue characteristics of the 39 economic deposits are used to assess the time distribution of average cash flows for an economic deposit. The undiscounted values are presented in figure 9 and summarized in table 5. The average cash flow generated by an economic deposit is $545 million. Based on the cash flow results portrayed in figure 9, assessments have been made of expected value criteria as presented in table 6.

As shown, base metal and gold exploration experience in Ontario represents an expenditure of approximately $1.4 billion, the result of which has been the discovery of 39 economic deposits. The average cost required to find and delineate an economic deposit is therefore about $37 million, equivalent to $29 million (E) when discounted at 8 percent to the start of the exploration phase. The reward for this exploration expenditure is an average return of $109 million (R) for each economic discovery. This return, the resultant of average development and production phase cash flows, is also expressed as a present value at the start of exploration. Consequently, the expected value of exploration per economic discovery is $109 million minus $29 million, or $80 million (EV). This means that, on average, based on the assumed conditions, $80 million of new wealth or economic surplus is associated with the discovery of an economic deposit. Alternatively, the expected value of exploration may be expressed as an 18-percent expected rate of return in relation to the 8-percent cost of capital.

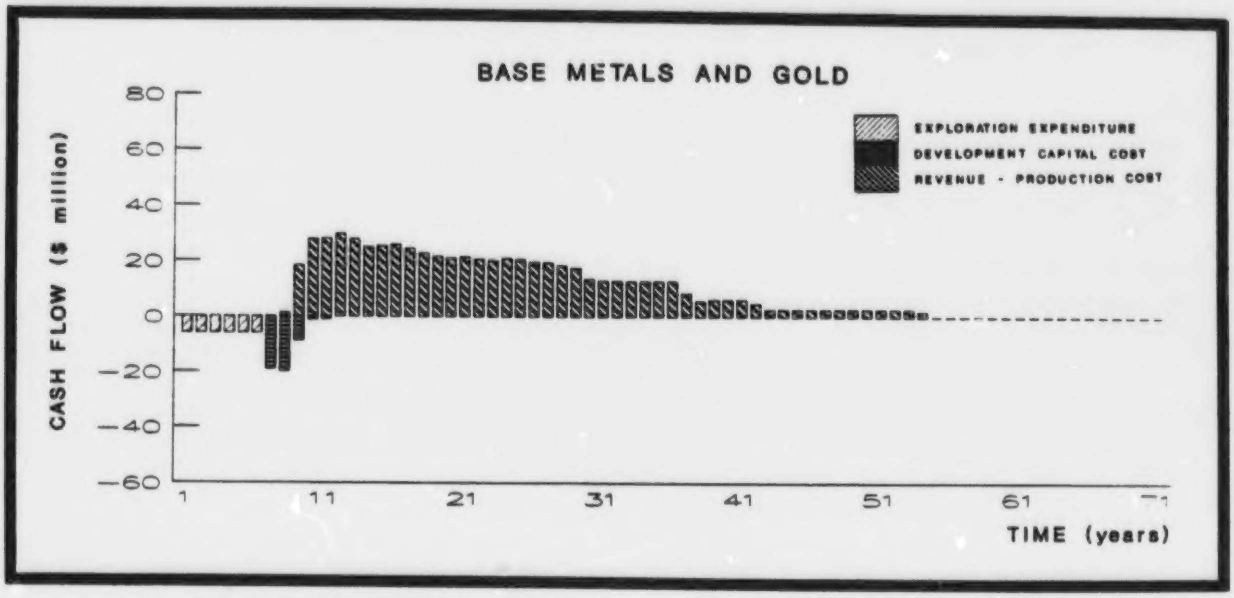


Figure 9. Time Distribution of Average Cash Flows for an Economic Deposit: Base Case Conditions

Table 5

AVERAGE CASH FLOW CHARACTERISTICS FOR AN ECONOMIC DEPOSIT UNDER BASE CASE CONDITIONS

Characteristic	Ontario
Time periods (years):	
Exploration phase	6
Development phase (maximum)	5
Production phase (maximum)	47
Undiscounted values ($ million):	
Revenue	985
Exploration expenditure	38
Development capital cost	50
Production cost	352
Cash flow	545

Table 6

EXPECTED VALUES FOR MINERAL EXPLORATION IN ONTARIO UNDER BASE CASE CONDITIONS

Category	Ontario
Total exploration expenditures ($ million)	1,449
Number of economic discoveries	39
Average exploration expenditure (E, $ million)	29
Average return (R, $ million)	109
Expected value (EV, $ million)	80
Rate of return (percent)	18

Base case results indicate that mineral exploration has the potential to increase substantially the net value or wealth available to Ontario society.

Comparison of Base Metal and Gold Exploration Potential

Separating the base case into two commodity groups - base metals and gold - we find that 9 of the 34 base metal discoveries (26 percent) and 30 of the 36 gold discoveries (83 percent) are economic. The time distributions of average cash flows for an economic deposit are compared in figure 10 and table 7. Assessments of the expected values of base metal and gold exploration are summarized in table 8.

Results indicate that the economic potential of both base metal and gold exploration are decidedly positive. The expected values per economic discovery are shown to be $87 million and $58 million, and the expected rates of return are 13 percent and 19 percent respectively. While these end results are somewhat similar, it is evident from figure 10 that base metal and gold exploration have quite different economic make ups.

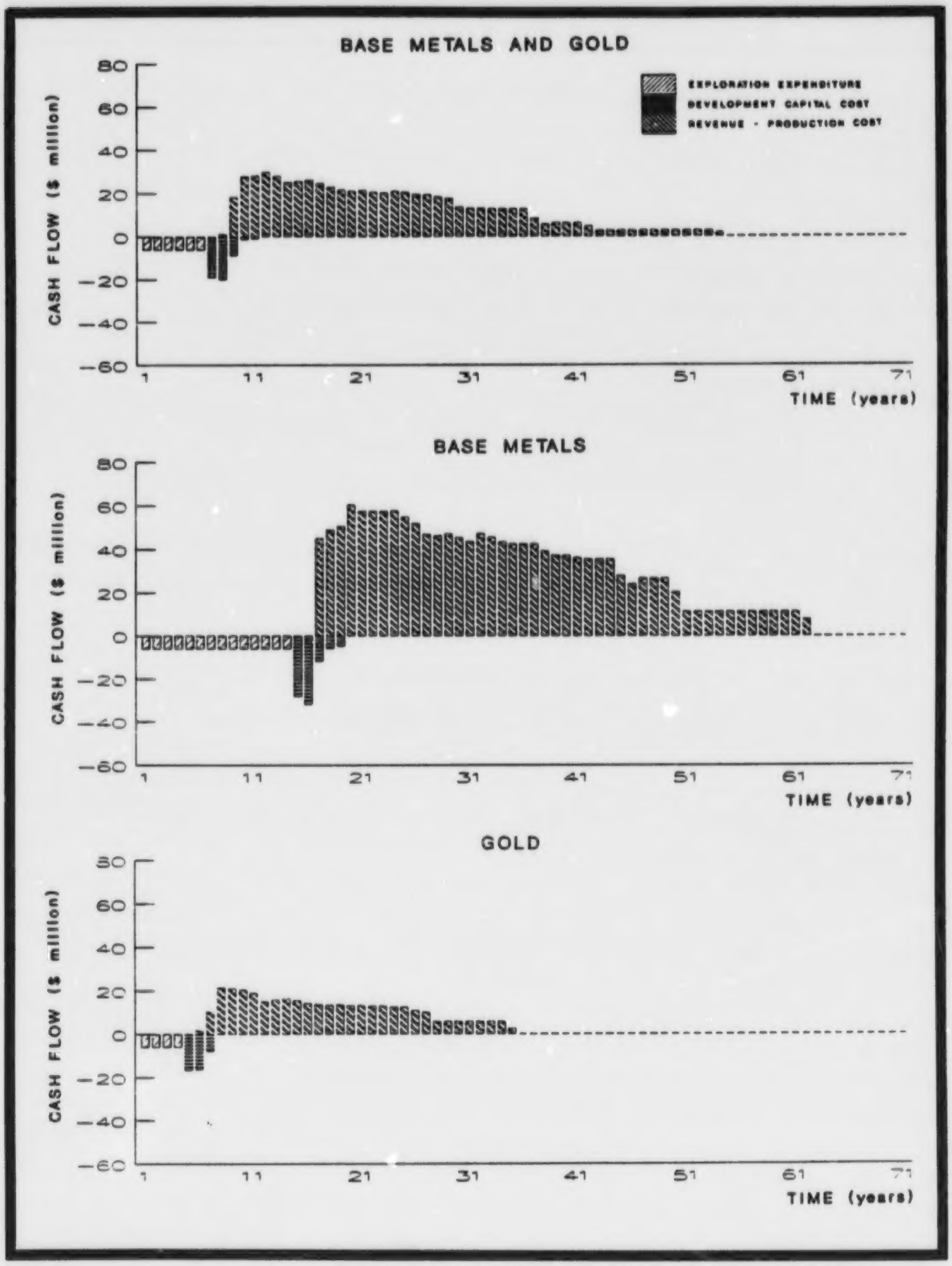


Figure 10. Time Distributions of Average Cash Flows for an Economic Deposit: Comparison of Base Metal and Gold Exploration

Table 7

AVERAGE CASH FLOW CHARACTERISTICS FOR AN ECONOMIC DEPOSIT BY COMMODITY GROUPING

Characteristic	Base Metals	Gold
Time periods (years):		
Exploration phase	14	4
Development phase (maximum)	5	3
Production phase (maximum)	46	30
Undiscounted values ($ million):		
Revenue	2,535	521
Exploration expenditure	86	23
Development capital cost	83	41
Production cost	959	170
Cash flow	1,407	287

Table 8

EXPECTED VALUES FOR MINERAL EXPLORATION IN ONTARIO BY COMMODITY GROUPING

Category	Base Metals	Gold
Total exploration expenditures ($ million)	742	707
Number of economic discoveries	9	30
Average exploration expenditure (E, $ million)	50	20
Average return (R, $ million)	137	78
Expected value (EV, $ million)	87	58
Rate of return (percent)	13	19

Total exploration expenditures are comparable ($742 million for base metals and $707 million for gold) but the resulting number of economic gold discoveries is more than three times greater (30 versus 9). In other words, historical experience suggests that an economic base metal deposit in Ontario costs three times as much and takes three times as long to find and delineate as an economic gold deposit.[8]

While base metal exploration is relatively costly and time consuming, the economic deposits that have been discovered are typically five times as large on average in terms of total revenue generated as the size of the economic gold deposits (table 7). This feature is to some extent masked in table 8 by the discounting effects associated with the long average base metal exploration period (14 years). However, the superiority of base metal discoveries in this regard can be seen by inspecting the cash flow characteristics for the undiscounted development and production phases in figure 10 and table 7.

Mine Development Economics

Base Case Results

The time distribution of average cash flows for an economic deposit as viewed from the start of development is illustrated in figure 11. This diagram reproduces the development and production phase cash flows shown in figure 9.

---

[8]. With the rise of free-market gold prices from the 1970s, the most obvious and attractive targets for gold exploration in Ontario are known occurrences in the old gold mining districts. The relatively low cost and short time assessed for gold exploration is at least in part a reflection of this tendency. While Ontario offers many opportunities of this type, they are being systematically followed up and depleted. With time, there will inevitably be a shift in Ontario's gold exploration away from the presently low cost and low risk re-evaluation of known occurrences towards higher cost and higher risk primary exploration targets. As this occurs, the gap found here between gold and base metal discovery costs and times will narrow.

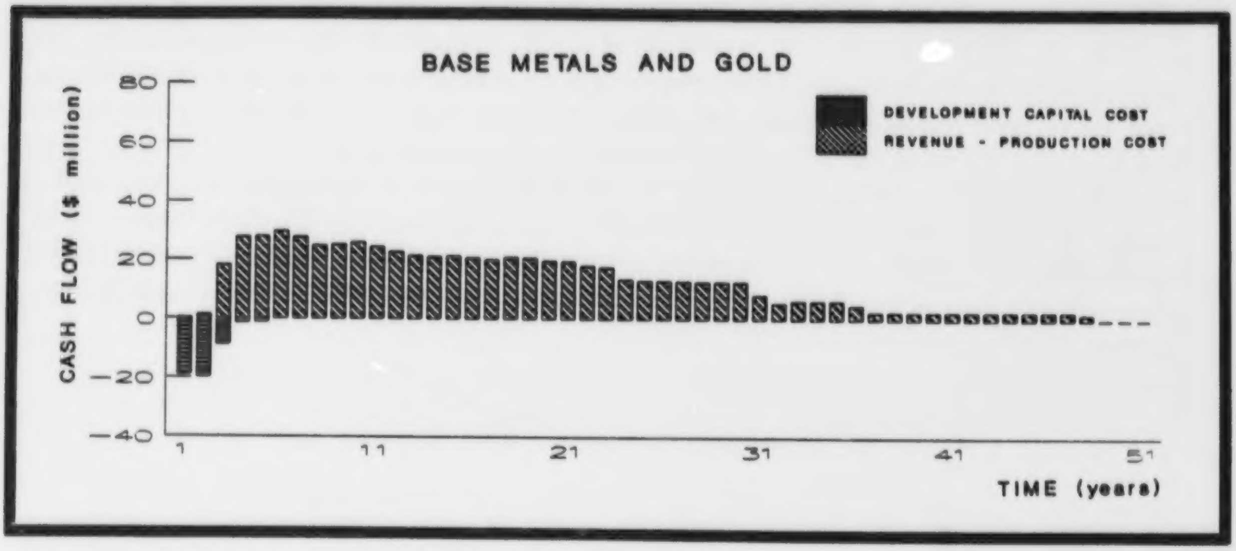


Figure 11. Time Distribution of Average Cash Flows for an Economic Deposit as Viewed from the Start of Development: Base Case Conditions

The economics of mine development can be characterized by the expected net present value of $177 million and the expected rate of return of 46 percent assessed from the cash flow distribution. Given an economic mineral deposit at the start of development, mining is shown to offer great potential for profitable investment and wealth creation.

The difference between the expected values of mine development - $177 million and 46 percent - and the expected values previously evaluated for mineral exploration - $80 million and 18 percent - provides an economic measure of exploration's contribution to the mineral supply process. Successful exploration is required to realize the enhanced economic returns offered at the start of development. This enhancement of expected values is the result of a selective, sequential information-gathering process that, starting with a broad exploration environment of interest (Ontario in this case), resolves the discovery and geologic risks, finding and delineating a mineral deposit which has economic potential for development.

Variability of Returns for Individual Deposits

The cash flow distribution presented in figure 11 averages together the cost and revenue characteristics for the 39 economic deposits assessed in Ontario. These discoveries are listed in table 9.[9] The economic potential of mine development is determined in each case by the deposit's particular characteristics. These are averaged together with 38 other widely ranging sets of deposit characteristics to appraise the composite typical deposit profile shown in figure 11.

Table 9

ECONOMIC DEPOSITS ASSESSED IN ONTARIO FOR BASE CASE CONDITIONS

Annco
Bell Creek
Broulan Reef
Cameron Lake
Carshaw
Dona Lake
Favourable Lake
Geco
Golden Patricia
Golden Rose
H.G. Young
Hemlo
Highland Crow
Hoyle Pond
Hugh Pam
Kidd Creek
Kremzar
Lyon Lake
Magino
Matheson East
Mattabi
McBean
McDermott
Magnacon
Nighthawk Lake
Opapamiskan
Owl Creek
Robin Red Lake
Romfield
St. Andrews
Schumacher Copper
Scadding
Shoal Lake
South Bay
Sturgeon
Surluga
Tisdale
Willroy
Winston Lake

---

[9] It is of interest to note that 25 of the 39 economic deposits assessed, including the three largest, occur in the Abitibi subprovince of the Superior province of the Canadian shield. This particular geologic area, which extends into Quebec, hosts by far the most productive greenstone belts and, consequently, the best base metal and gold deposits, in the entire shield region. It is also the most intensively explored region and is easily accessible.

The high degree of variability in the returns associated with the development of economic discoveries - a consequence of the variability in tonnage, grade, and other geologic characteristics among economic deposits - is an essential feature of the mineral supply process. To illustrate this point, we have examined the cumulative frequency distributions of total revenue, net present value, and rate of return for the 39 economic deposits assessed in Ontario under the assumed base case conditions. Key statistics from these distributions are summarized in table 10.

Table 10

VARIABILITY OF THE RETURN FOR ECONOMIC DEPOSITS IN ONTARIO

Statistic	Total Revenue ($ million)	Net Present Value ($ million)	Rate of Return (percent)
Upper decile	1,728	391	87
Upper quartile	301	60	50
Mean (average)	985	177	46
Median	161	30	31
Lower quartile	121	11	18
Lower decile	34	4	13

Notes: based on expected metal prices; total revenue is evaluated at the minesite; net present value is determined at the start of development using an 8-percent discount rate.

Total revenue, evaluated in this case at the minesite, reflects deposit size. Table 10 indicates that there is a 50-times difference in size between the lower-decile and upper-decile economic deposits around the mean value of $985 million. The total revenue distribution is also shown to be highly skewed. There are many small economic discoveries and a few that are very large (Kidd Creek, Hemlo, and Geco). Thus, the mean value for total revenue ($985 million) is more than 3-times higher than the revenue for the upper-quartile deposit ($301 million), and 6-times greater than the median or middle value of the distribution ($161 million).

Rate of return measures the profitability of an economic deposit. The rate of return distribution for the 39 economic deposits is shown in table 10 to be less variable and not as skewed as the size (total revenue) distribution. There is a 7-fold difference in rate of return between the lower-decile and upper-decile economic deposits (13 percent and 87 percent respectively). The mean rate of return (46 percent) lies between the median and upper-quartile values.

Turning to the net present value results, which provide a combined indicator of size and profitability characteristics, the mean or average value is $177 million. The variability of the return, given an economic deposit, is illustrated by the almost 100-fold difference in value between the lower-decile and upper-decile economic deposits ($4 million and $391 million respectively). Like the size distribution, the net present value distribution is highly skewed. There are many low-value economic discoveries and relatively few of extremely high value. As a consequence, the mean value of the economic deposits ($177 million) falls between the values for the upper-quartile and upper-decile deposits ($60 million and $391 million respectively).

With respect to government policy formulation, the main message that the results presented in table 10 convey is that there is no such thing as a "typical deposit". Thus, flexibility is required in government policies to equitably and efficiently accommodate the wide range of returns associated with mine development.

Comparison of Base Metal and Gold Mine Development Potential

The time distributions of average cash flows for economic base metal and gold deposits as viewed from the start of development are compared in figure 12. These distributions are the same as those previously shown for the development and production phases in figure 10. The associated economic criteria are summarized in table 11.

The economic base metal deposits are shown to be about 5-times larger on average than the economic gold deposits. Also, their potential development is typically more profitable as indicated by the expected rate of return results (57 percent versus 38 percent). Combining these size and profitability attributes, the net present value of an economic base metal deposit averages $416 million, about 4-times greater than the average value of an economic gold deposit ($105 million).

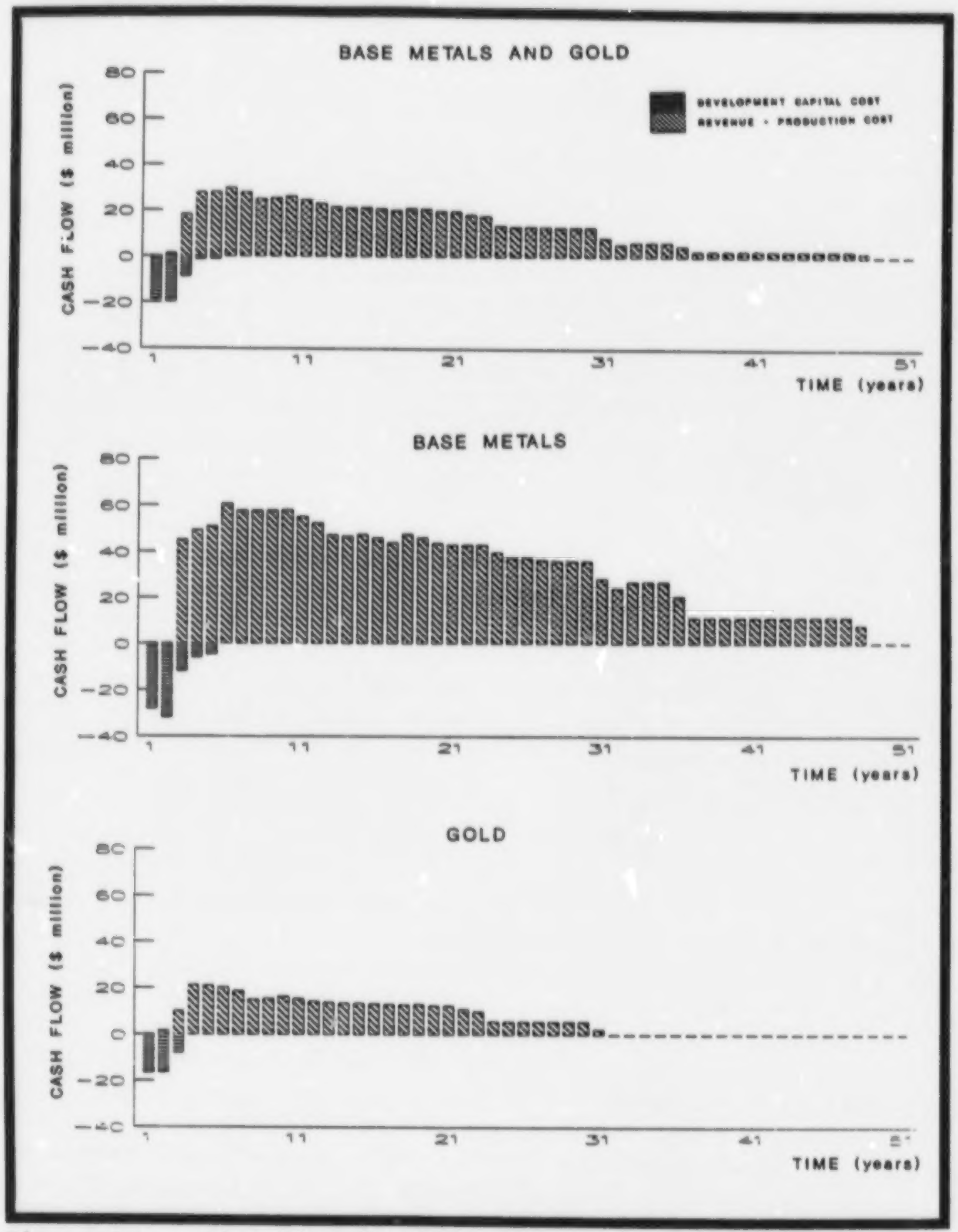


Figure 12. Time Distributions of Average Cash Flows for an Economic Deposit as Viewed from the Start of Development: Comparison of Base Metal and Gold Mine Development

Table 11

EXPECTED VALUES FOR MINE DEVELOPMENT IN ONTARIO BY COMMODITY GROUPING

Category	Base Metals	Gold
Total revenue ($ million)	2,535	521
Net present value ($ million)	416	105
Rate of return (percent)	57	38

Note: the net present value is determined by discounting the cash flows at 8 percent to the start of development.

Key statistics illustrating the variability of the return for economic base metal and gold deposits are compared in table 12. These results once again show the very wide range of size and profitability characteristics associated with mine development opportunities. The superiority of base metal deposits relative to gold deposits generally holds throughout these distributions with the exception of the lower half of the rate of return distribution.

Summing Up

The economic potential for gold and base metal exploration and mine development in Ontario is shown to be substantial.

In the long term, as viewed from the start of exploration, Ontario's mineral supply process is characterized by an expected value of $80 million per economic deposit discovered and by an 18-percent expected rate of return in relation to the 8-percent cost of capital considered.

In the medium term, the economic return characteristics at the start of mine development are typified by a net present value of $177 million per economic mineral deposit and by a 46-percent rate of return of investment. The enhancement in potential values which occurs between the start of exploration and the start of mine development illustrates exploration's strategic role in the mineral supply process.

Table 12

COMPARISON OF BASE METAL AND GOLD MINE DEVELOPMENT: VARIABILITY OF THE RETURN FOR ECONOMIC DEPOSITS

	Total Revenue ($ million)		Net Present Value ($ million)		Rate of Return (percent)	
Statistic	Base Metals	Gold	Base Metals	Gold	Base Metals	Gold
Upper decile	15,175	441	2,508	87	113	86
Upper quartile	2,682	211	469	49	71	48
Mean (average)	2,535	521	116	105	57	38
Median	455	152	78	25	27	35
Lower quartile	281	69	25	8	15	21
Lower decile	183	32	16	3	13	13

Notes: based on expected metal prices; total revenue is evaluated at the minesite; net present value is determined at the start of development using an 8-percent discount rate.

A high degree of variability is shown in the return characteristics of individual economic deposits around the composite values appraised. These striking differences reflect the underlying variability in deposit size, grade, and other geological parameters among the economic discoveries.

While results for the base metal and gold commodity groupings are both shown to be decidedly positive and somewhat similar, they have quite different economic make ups. Historical experience suggests that an economic base metal deposit in Ontario costs three times as much and takes three times as long to find and delineate on average as an economic gold deposit. On the other hand, the economic base metal deposits that have been discovered tend to be 5-times larger as well as more profitable than the economic gold deposits.

The representative features of mineral exploration and mine development in Ontario assessed here are broad generalizations across a wide range of experience. Any particular situation should not of course be expected to reproduce these averages. Nevertheless, the numerical values appraised provide a useful overall portrait of the mineral supply process that can be used when looking ahead to assess the general requirements for and consequences of mineral policy formulation and decision making.

5. SENSITIVITY OF POTENTIAL VALUES TO KEY STUDY PARAMETERS

The potential value assessments presented in chapter 4 are based on a particular set of base case conditions. We are uncertain about a number of the conditions assumed. In the present chapter, the more general validity of the mineral exploration and mine development results is examined using sensitivity analysis. The key parameters selected for attention here are metal prices, the annual exploration budget, the cost of capital, and the effect of the multi-billion dollar discovery.

Mineral Exploration Economics

Metal Price Variants

The expected metal prices used in chapter 4 represent highly uncertain "best" estimates. Potential value assessments for mineral exploration as a function of the lower-limit, expected, and upper-limit metal price conditions specified in table 3 are shown in figure 13 and table 13.

These results indicate a high degree of sensitivity of the economics of exploration to metal price uncertainties. As metal prices increase, there are sharp increases in the number of economic discoveries, in the average return associated with an economic discovery, and in the expected value per economic discovery and expected rate of return. At the same time, higher metal prices reduce the average exploration expenditure and the average time required to discover and delineate an economic deposit.[10] Thus, as discussed in chapter 2, the uncertainty associated with metal price forecasts represents an important risk in corporate planning and government policy analysis. Flexibility should be incorporated in plans and policies to accommodate the resolution of price uncertainties with time.

---

[10] This is because more discoveries satisfy the definition of "economic deposit", it is not due to integral change in the exploration process.

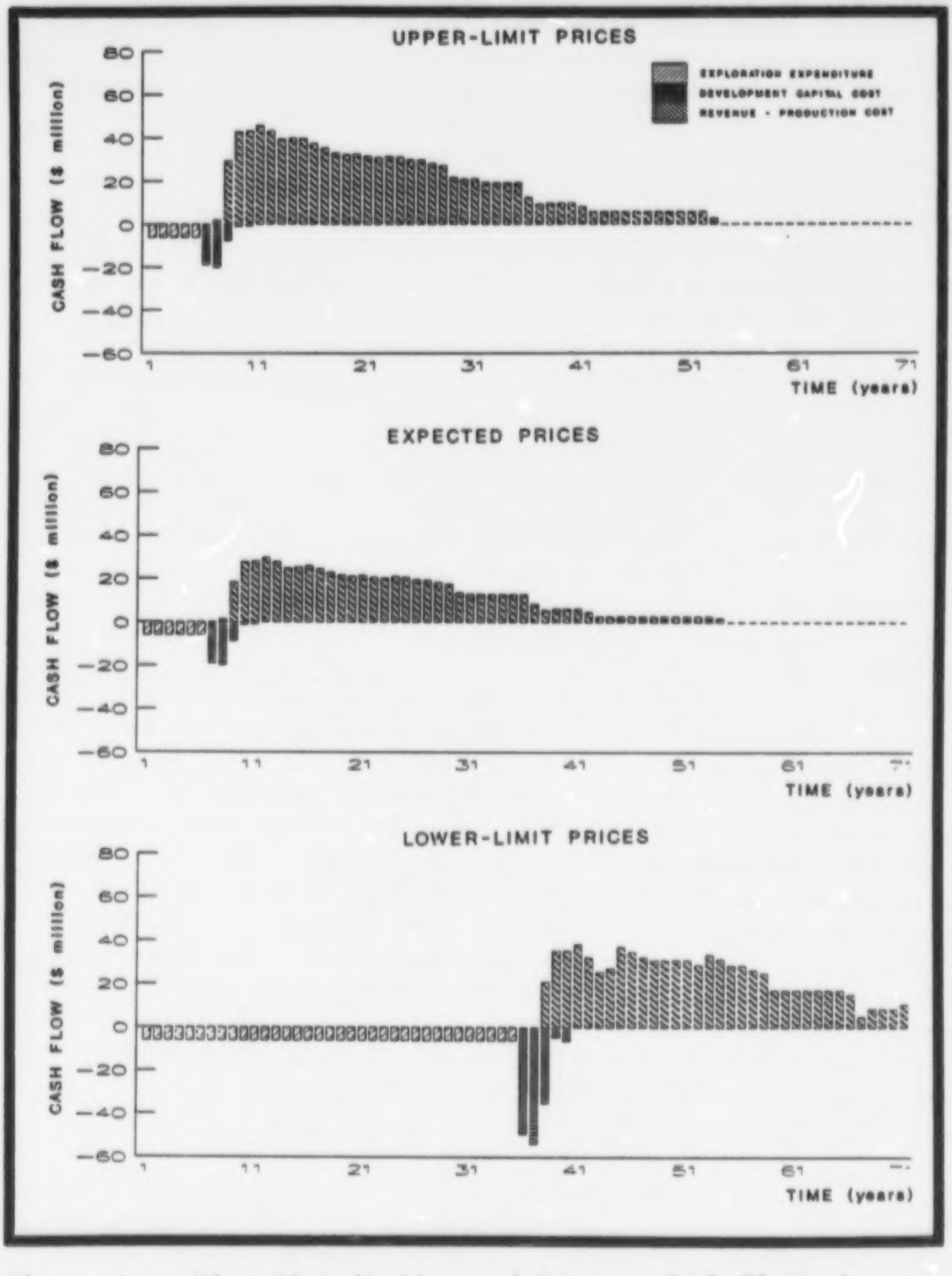


Figure 13. Time Distributions of Average Cash Flows for an Economic Deposit as a Function of Metal Price

Table 13

EXPECTED VALUES FOR MINERAL EXPLORATION IN ONTARIO AS A FUNCTION OF METAL PRICE

Category	Price Variant		
	Lower-Limit	Expected	Upper-Limit
Total exploration expenditures ($ million)	1,449	1,449	1,449
Number of economic discoveries	7	39	48
Average exploration expenditure (E, $ million)	70	29	25
Average return (R, $ million)	11	109	202
Expected value (EV, $ million)	-59	80	177
Rate of Return (percent)	3	18	28

Variants with Respect to the Annual Exploration Budget

An annual exploration budget rate of $6.0 million, considered to be among the most efficient rates of expenditure (chapter 2), is incorporated in the evaluation carried out in chapter 4. This assumption has a critical bearing on the potential value of exploration because it is a determinant of the average time required to discover and delineate economic deposit. At this rate of expenditure, we estimated that 6 years of exploration are required on average for an economic deposit in Ontario.

Assessments of the economics of exploration have also been made for annual exploration budgets of $3.0 million and $9.0 million. The effects of these budget rates on the expected value measures are shown in table 14. As the annual exploration budget is increased, a significant improvement in results is apparent. By reducing the average exploration time required for an economic deposit, the time distribution of negative cash flows is shortened and the time distribution of positive cash flows moves toward the present. Thus, although total exploration expenditures and the number of economic deposits remain constant, the potential value of mineral exploration is enhanced.

Table 14

EXPECTED VALUES FOR MINERAL EXPLORATION IN ONTARIO AS A FUNCTION OF THE ANNUAL EXPLORATION BUDGET

	Budget Variant		
Category	$3.0 Million	$6.0 Million	$9.0 Million
Total exploration expenditures ($ million)	1,449	1,449	1,449
Number of economic discoveries	39	39	39
Average exploration expenditure (E, $ million)	23	29	31
Average return (R, $ million)	66	109	127
Expected value (EV, $ million)	43	80	96
Rate of Return (percent)	14	18	19

Cost of Capital Variants

A constant money cost of capital of 8 percent is used in the base case to evaluate the economic potential of base metal and gold exploration in Ontario. To analyze the sensitivity of study results to the cost of capital, assessments are also made for 5 percent and 12 percent rates. Results are presented in table 15.

Table 15

EXPECTED VALUES FOR MINERAL EXPLORATION IN ONTARIO AS A FUNCTION OF THE COST OF CAPITAL

	Cost-of-Capital Variant		
Category	5 Percent	8 Percent	12 Percent
Total exploration expenditures ($ million)	1,449	1,449	1,449
Number of economic discoveries	40	39	38
Average exploration expenditure (E, $ million)	31	29	26
Average return (R, $ million)	189	109	54
Expected value (EV, $ million)	158	80	28
Rate of Return (percent)	18	18	18

Raising the minimum rate-of-return requirement has only a modest effect on reducing the number of economic deposits because, as we have already seen (table 10), very few of the deposits lie close to the investment margin. As the number of deposits which would be economic decreases from 40 to 38, the direct cost of discovering an economic deposit increases somewhat. However, the average exploration expenditure expressed as a time adjusted value at the start of exploration (E) decreases as shown from $31 million to $26 million because the effect of the higher discount rate used more than offsets the direct cost increase.

As shown in table 15, the strongest economic effect is the reduction in the average return (R). Since the time distribution of revenues for all economic deposits lies further into the future than the time distribution of development capital cost, heavier discounting resulting from a higher cost of capital reduces discounted revenues more than discounted costs. This lowers the average return and, consequently, the expected value associated with an economic deposit (EV). While the expected rate of return remains unchanged at 18 percent, the rate of return - cost of capital differential narrows appreciably as the hurdle rate is raised from 5 percent to 12 percent.

Effect of the Multi-Billion Dollar Discovery

The Kidd Creek base metal deposit and the Hemlo gold deposit are the two most important economic discoveries made in Ontario (and in Canada) during the study period. The effect of these discoveries on the economics of exploration is examined by hypothetically removing them from the assessment of expected values. Comparative results, presented in figure 14 and table 16, show that these two deposits - among 39 economic deposits - represent a substantial part of Ontario's economic mineral potential and have a profound effect on the economics of mineral exploration. Within their respective commodity groupings as well as for the combined base metal and gold totals, the Kidd Creek and Hemlo deposits are shown in table 16 to make the difference between Ontario being a province with high prospects for exploration investment and what would otherwise be a marginal environment on average.

If these very rare deposits did not occur, the economics of mineral exploration would be impoverished. The possibility that any exploration program can lead to a multi-billion dollar discovery, although extremely improbable, is no doubt a great motivator in mineral exploration. Such a valuable target likely carries weight in exploration decisions beyond its actual numerical contribution to the expected value measures illustrated here.

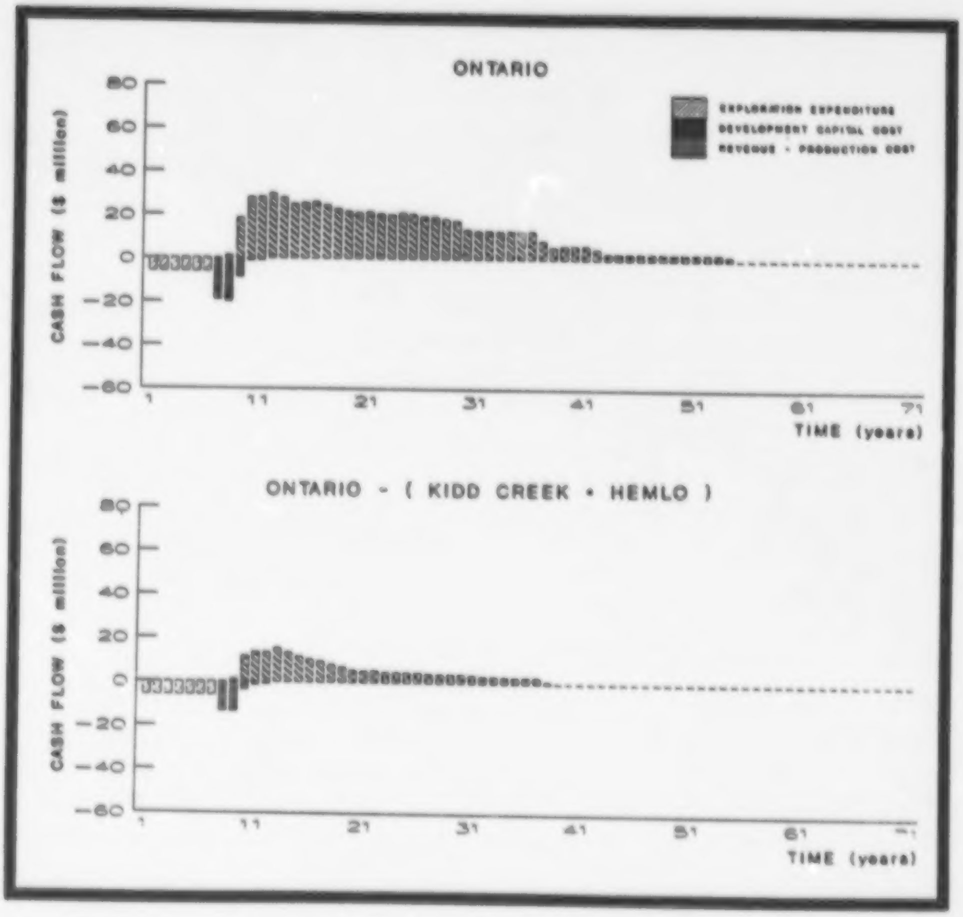


Figure 14. Time Distributions of Average Cash Flows for an Economic Deposit: Effect of the Multi-Billion Dollar Discovery

Mine Development Economics

The sensitivity of the average total revenue, the expected net present value, and the expected rate of return of economic deposits at the start of development to metal price, cost of capital, and hypothetical removal of the Kidd Creek and Hemlo discoveries is summarized in table 17. The potential value of mine development is shown to be highly sensitive to possible variations in metal price and the multi-billion dollar discovery. The net present value measure is also sensitive to the cost of capital. These findings are consistent with the sensitivities previously shown for mineral exploration.

Table 16

EXPECTED VALUES FOR MINERAL EXPLORATION IN ONTARIO: EFFECT OF THE MULTI-BILLION DOLLAR DISCOVERY

	Total Exploration Expenditures ($ million)	Number of Economic Discoveries	Average Exploration Expenditure (E,$ mill.)	Average Return (R,$ mill.)	Expected Value (EV,$ mill.)	Rate of Return (%)
Base Metals:						
With Kidd Creek	742	9	50	137	87	13
Without Kidd Creek	742	8	53	44	-9	7
Gold:						
With Hemlo	707	30	20	78	58	19
Without Hemlo	707	29	20	22	2	9
Base Metals and Gold:						
With Kidd Creek and Hemlo	1,449	39	29	109	80	18
Without Kidd Creek and Hemlo	1,449	37	30	34	4	9

Table 17

SENSITIVITY OF POTENTIAL VALUES OF MINE DEVELOPMENT TO KEY STUDY PARAMETERS

Parameter	Total Revenue ($ million)	Net Present Value ($ million)	Rate of Return (percent)
Metal Price Variants:			
Lower-Limit	1,995	160	21
Expected	985	177	46
Upper-Limit	1,313	300	68
Cast of Capital Variants:			
5 percent	961	256	45
8 percent	985	177	46
12 percent	1,011	114	46
Effect of the Multi-Billion Dollar Discovery:			
With Kidd Creek and Hemlo	985	177	46
Without Kidd Creek and Hemlo	328	57	36

The relationship between price levels and the average total revenue per economic discovery requires an explanation. As metal prices are raised from lower-limit to expected levels, the number of economic deposits increases from 7 to 39 (table 13). The relatively small size and low total revenue characteristics of the 32 deposits that are added outweigh the effect of the higher prices on the total revenue for the 7 deposits that remain economic. Consequently, the average total revenue per economic deposit at expected prices is less than half that assessed at lower-limit prices. Then, as prices are further increased from expected to upper-limit levels, the effect of the higher prices on the 33 deposits predominates over the contribution of the additional 9 deposits. Consequently, the average total revenue per economic deposit increases through this price interval as shown in table 17.

As the cost of capital is increased from 5 percent to 12 percent, the average total revenue per economic deposit rises modestly because of the relatively small size of the two deposits screened out.

Removal of the Kidd Creek and Hemlo deposits is shown in table 17 to have a stronger effect on average deposit size than on profitability. Without these two deposits, the average total revenue and the expected net present value per economic deposit would both fall to approximately one third of their base case values. While the reduction in the expected rate of return is also significant, it is not as pronounced.

Summing Up

We have tested the base case findings presented in chapter 4 to realistic ranges of possible future conditions. The economic potential of mineral exploration and mine development in Ontario is found to be particularly sensitive to future metal prices. Government policies should have the flexibility to adjust to the resolution of uncertainties associated with this critical market parameter. The annual exploration budget rate and the cost of capital also have appreciable impacts on the potential value assessments.

The Kidd Creek base metal deposit and the Hemlo gold deposit, both of which occur in Ontario, most likely represent the two most important mineral discoveries made in Canada since the second world war. These two deposits, among 39 economic deposits evaluated in Ontario, are found to account for a substantial part of its economic mineral potential. They make the difference between Ontario being a province with high prospects for exploration investment and what would otherwise be a marginal environment on average. The possibility that any exploration program can lead to another multi-billion dollar discovery of this calibre provides a great investment incentive.

6. ONTARIO'S COMPETITIVE STANDING IN THE SHIELD REGION AND IN CANADA

Having examined the economic potential of mineral exploration and mine development in Ontario, the purpose of this chapter is to provide a comparative context. How do the results for Ontario compare with similar appraisals for the shield region and for Canada? What is Ontario's competitive standing in terms of the potential value of mineral supply to society?

Mineral Exploration Economics

Base Metal and Gold Exploration

Time distributions of average cash flows for an economic deposit in Ontario, the shield region, and Canada are compared in figure 15. The undiscounted cash flow characteristics are summarized in table 18. Table 19 presents the associated assessments of expected value criteria.

Table 18

ONTARIO'S COMPETITIVE STANDING: AVERAGE CASH FLOW CHARACTERISTICS FOR ECONOMIC DEPOSITS

Characteristic	Ontario	Shield Region	Canada
Time periods (years):			
Exploration phase	6	6	6
Development phase (maximum)	5	5	5
Production phase (maximum)	47	49	49
Undiscounted values ($ million):			
Revenue	985	590	908
Exploration expenditure	38	34	36
Development capital cost	50	45	74
Production cost	352	229	416
Cash flow	545	282	382

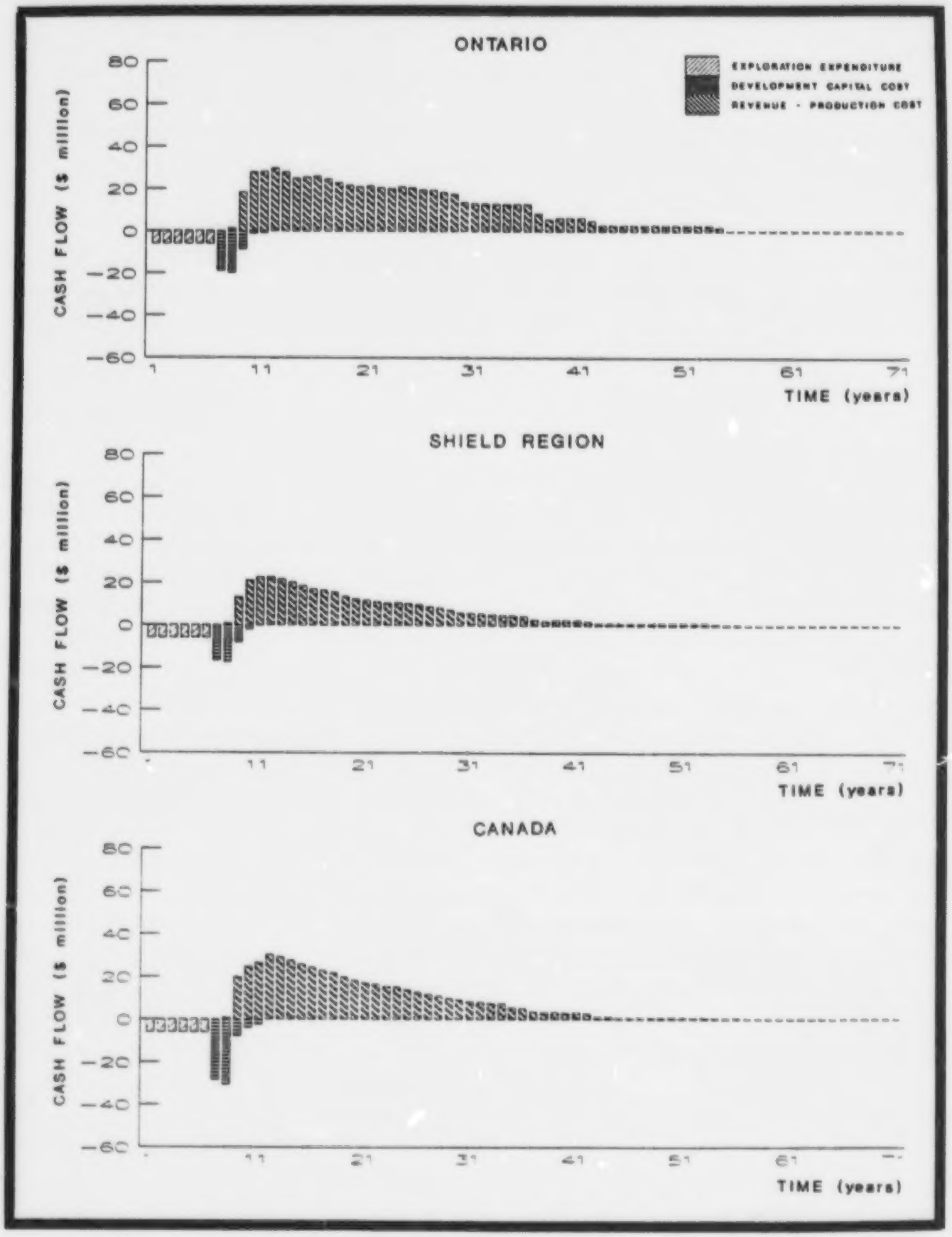


Figure 15. Time Distributions of Average Cash Flows for an Economic Deposit: Ontario's Competitive Standing

Table 19

ONTARIO'S COMPETITIVE STANDING: EXPECTED VALUES FOR MINERAL EXPLORATION

Category	Ontario	Shield Region	Canada
Total exploration expenditures ($ million)	1,449	4,214	7,661
Number of economic discoveries	39	125	209
Average exploration expenditure (E, $ million)	29	26	28
Average return (R, $ million)	109	69	85
Expected value (EV, $ million)	80	43	57
Rate of Return (percent)	18	15	15

The average exploration expenditure per economic discovery is remarkably similar in all three cases. The average return associated with the discovery of an economic deposit is, however, found to be significantly higher in Ontario than for the shield region and Canada overall. Consequently, the expected value per economic deposit and the expected rate of return are relatively high. Economic discoveries in Ontario during the 1946-85 study period appear to be both larger and more profitable than in the rest of Canada. The economics of mineral exploration in the province is therefore particularly attractive.

Base Metal Exploration

Looking more specifically at base metal exploration, the undiscounted cash flow values are compared in figure 16 and summarized in table 20. Expected value criteria, derived from these appraisals, are shown in table 21.

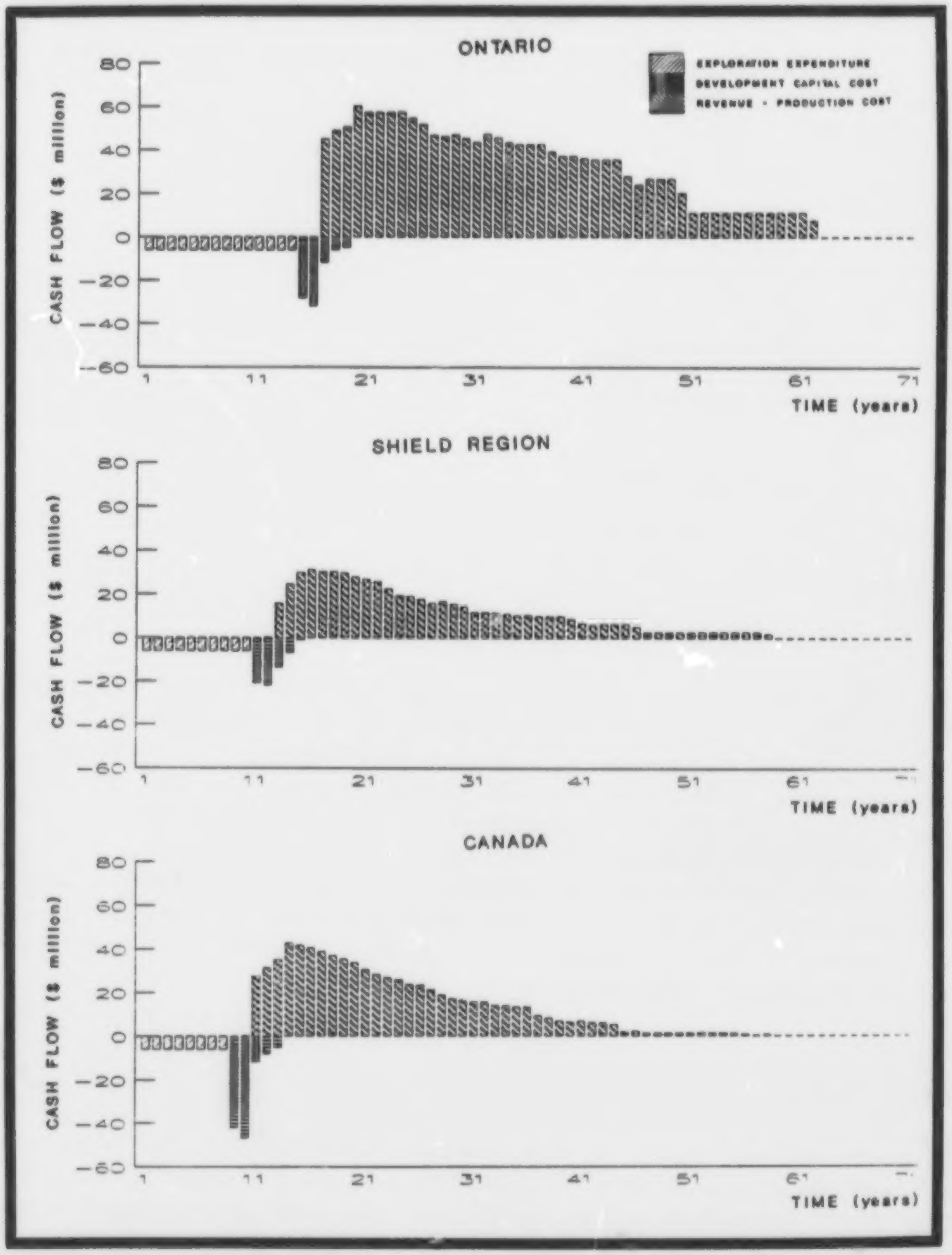


Figure 16. Time Distributions of Average Cash Flows for an Economic Base Metal Deposit: Ontario's Competitive Standing

Table 20

ONTARIO'S COMPETITIVE STANDING: AVERAGE CASH FLOW CHARACTERISTICS FOR AN ECONOMIC DEPOSIT BY COMMODITY GROUPING
($ million)

Commodity Grouping and Region	Undiscounted Values				
	Revenue	Exploration Expenditure	Development Capital Cost	Production Costs	Cash Flow
Base Metals:					
Ontario	2,535	86	83	959	1,407
Shield Region	958	60	65	376	457
Canada	1,429	50	114	681	584
Gold:					
Ontario	521	23	41	170	287
Shield Region	410	21	35	157	197
Canada	393	23	34	153	183

Table 21

ONTARIO'S COMPETITIVE STANDING: EXPECTED VALUES FOR MINERAL EXPLORATION BY COMMODITY GROUPING

Commodity Grouping and Region	Number of Economic Discoveries	Average Exploration Expenditure (E, $ mill.)	Average Return (R, $ mill.)	Expected Value (EV, $ mill.)	Rate of Return (%)
Base Metals:					
Ontario	9	50	137	87	13
Shield Region	41	40	74	34	12
Canada	104	35	100	65	14
Gold:					
Ontario	30	20	78	58	19
Shield Region	84	18	63	45	19
Canada	105	19	60	41	18

The average expenditure and the average time required to find and delineate an economic base metal deposit in Ontario are found to be relatively costly by both shield region and Canadian standards. This disadvantage tends to be offset, however, by the superior characteristics of the base metal deposits discovered. The net result in terms of the potential value of mineral exploration is shown in table 21 - the expected value per economic discovery is higher in Ontario, and the expected rate of return is similar to that assessed for the shield region and Canada.

Gold Exploration

With respect to gold exploration, the comparative cash flow distributions are illustrated in figure 17 and summarized in table 20. The associated expected value measures are presented in table 21.

Gold exploration experience appears to be more geographically homogeneous than is the case for base metals. Exploration expenditures per economic discovery (E) average $18-20 million in Ontario, the shield region, and Canada. The expected rate of return results are also similar. The average return (R) and the expected value per economic deposit (EV) are somewhat higher in the case of Ontario but differences with the shield region and Canada are relatively small.

Mine Development Economics

Average Returns

The expected values of mine development in Ontario, the shield region, and Canada are compared in table 22 for base metal and gold deposits taken together, and in table 23 for base metal and gold deposits as separate groupings. These results confirm some of the main points that arose earlier in the comparative exploration assessments:

- economic base metal deposits in Ontario are, on average, much larger and more profitable than in the rest of Canada;

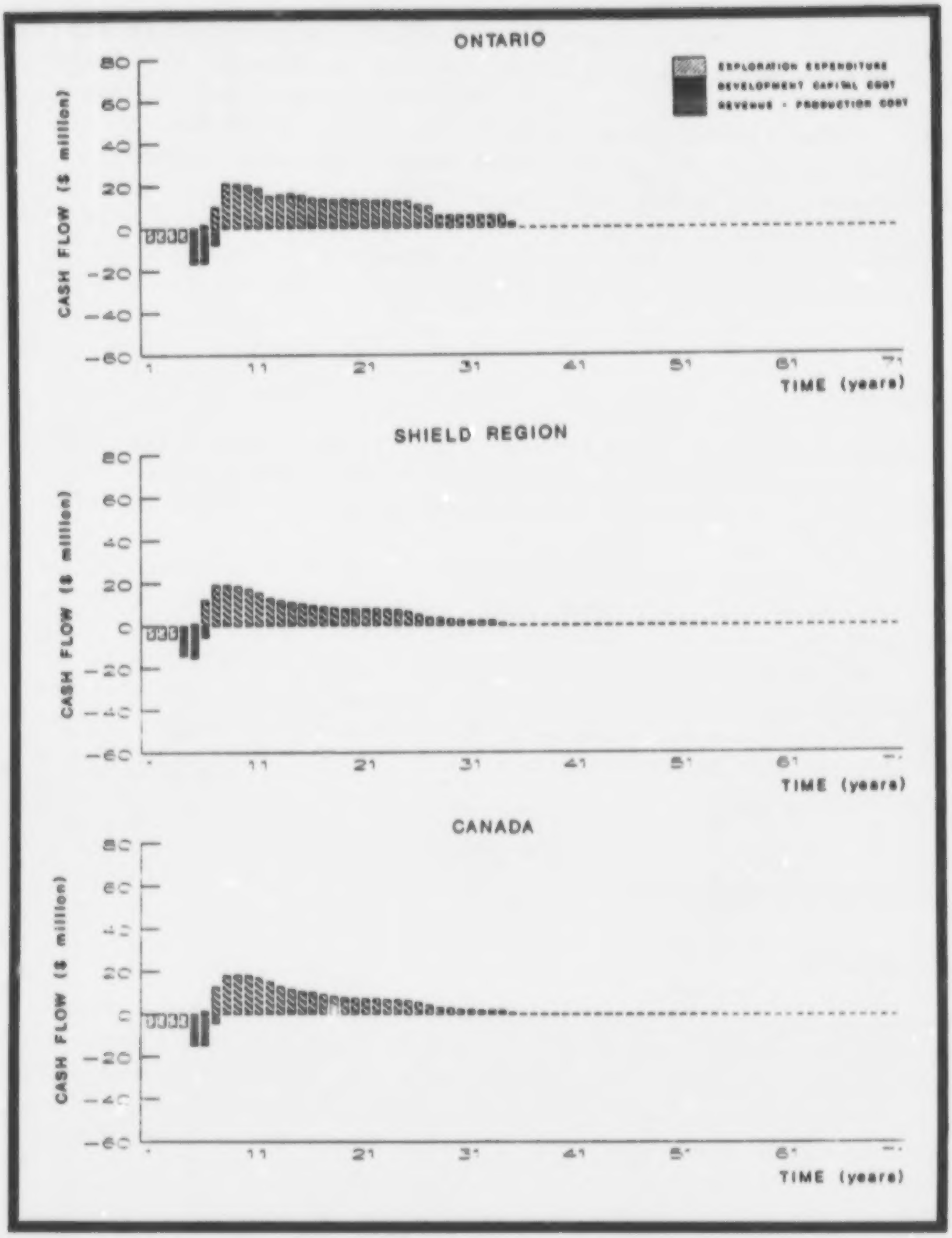


Figure 17. Time Distributions of Average Cash Flows for an Economic Gold Deposit: Ontario's Competitive Standing

Table 22

ONTARIO'S COMPETITIVE STANDING: EXPECTED VALUES FOR MINE DEVELOPMENT

Region	Total Revenue ($ million)	Net Present Value ($ million)	Rate of Return (percent)
Ontario	985	177	46
Shield region	590	107	39
Canada	908	135	32

Table 23

ONTARIO'S COMPETITIVE STANDING: EXPECTED VALUES FOR MINE DEVELOPMENT BY COMMODITY GROUPING

Commodity Grouping and Region	Total Revenue ($ million)	Net Present Value ($ million)	Rate of Return (percent)
Base Metals:			
Ontario	2,535	416	57
Shield Region	958	159	38
Canada	1,429	190	29
Gold:			
Ontario	521	105	38
Shield Region	410	82	41
Canada	393	80	41

- Ontario's economic gold deposits are somewhat larger and their potential profitability is similar on average to those discovered elsewhere in Canada;

- these specific findings explain the comparative results for economic base metal and gold deposits combined (table 22);

- in terms of total revenue, economic gold deposits tend to be one half to one fifth the size of the economic base metal deposits;

- the economic base metal deposits which occur in Ontario are more profitable on average than the economic gold deposits but, elsewhere in Canada, gold deposits are found to be more profitable than base metal deposits.

Variability of Returns

Cumulative distributions of total revenue, net present value, and rate of return for economic mine development opportunities in Ontario, the shield region, and Canada are compared in tables 24-26 in terms of key statistics for base metal and gold deposits together, base metal deposits, and gold deposits respectively. Besides further illustrating the high degree of variability in return characteristics that occurs among economic deposits throughout Canada, these comparative statistics help explain earlier findings as follows:

- the relatively large average size of base metal deposits in Ontario is mainly attributable to two very large deposits (Kidd Creek and Geco) in a small sample size, skewing the total revenue distribution as illustrated by Ontario's high upper-decile and upper-quartile statistics in table 25;

- a greater proportion of base metal deposits with high rates of return also occurs in Ontario;

Table 24

ONTARIO'S COMPETITIVE STANDING: VARIABILITY OF THE RETURN FOR ECONOMIC DEPOSITS

Statistic	Total Revenue ($ mill.)			Net Present Value ($ mill.)			Rate of Return (%)		
	Ontario	Shield Region	Canada	Ontario	Shield Region	Canada	Ontario	Shield Region	Canada
Upper decile	1,728	1,018	2,053	391	259	312	87	74	74
Upper quartile	301	468	799	60	86	113	50	47	49
Mean (average)	985	695	978	177	132	156	46	40	40
Median	161	212	289	30	38	46	31	31	31
Lower quartile	121	129	139	11	16	20	18	21	20
Lower decile	34	67	68	4	7	7	13	14	13

Notes: based on expected metal prices; total revenue is evaluated at the minesite; net present value is determined at the start of development using an 8-percent discount rate; includes economic base metal deposits discovered before 1946.

Table 25

ONTARIO'S COMPETITIVE STANDING: VARIABILITY OF THE RETURN FOR ECONOMIC BASE METAL DEPOSITS

Statistic	Total Revenue ($ mill.)			Net Present Value ($ mill.)			Rate of Return (%)		
	Ontario	Shield Region	Canada	Ontario	Shield Region	Canada	Ontario	Shield Region	Canada
Upper decile	15,175	1,958	3,429	2,508	448	471	113	69	70
Upper quartile	2,682	793	1,604	469	126	179	71	40	44
Mean (average)	2,535	1,156	1,434	416	213	215	57	34	34
Median	455	390	458	78	47	63	27	26	27
Lower quartile	281	230	222	25	25	29	15	19	16
Lower decile	183	111	114	16	10	9	13	13	12

Notes: based on expected metal prices; total revenue is evaluated at the minesite; net present value is determined at the start of development using an 8-percent discount rate; includes economic base metal deposits discovered before 1946.

Table 26

ONTARIO'S COMPETITIVE STANDING: VARIABILITY OF THE RETURN FOR ECONOMIC GOLD DEPOSITS

	Total Revenue ($ mill.)			Net Present Value ($ mill.)			Rate of Return (%)		
	Ontario	Shield Region	Canada	Ontario	Shield Region	Canada	Ontario	Shield Region	Canada
Upper decile	411	790	618	87	153	155	87	81	81
Upper quartile	211	301	321	49	56	68	50	51	58
Mean (average)	521	410	323	105	82	80	46	44	46
Median	152	163	164	25	32	38	35	36	37
Lower quartile	69	99	99	8	12	14	21	22	24
Lower decile	32	58	51	3	7	5	13	16	17

Notes: based on expected metal prices; total revenue is evaluated at the minesite; net present value is determined at the start of development using an 8-percent discount rate; includes economic base metal deposits discovered before 1946.

- the somewhat higher mean values for total revenues and net present value for economic gold deposits in Ontario appear to be attributable to the Hemlo deposit which falls above the upper-decile statistics. Otherwise, the return characteristics in Ontario are less attractive than those which more generally characterize the shield region and Canada;

- the rate of return distributions for economic gold deposits in the three areas are quite similar.

Comparative Endowment and Return Characteristics for Deposits Discovered Before and During the Study Period

Considering the complete timeframe of historical experience, table 27 compares average endowment characteristics of possible economic base metal deposits discovered before and during the 1946-85 study period. Pre-1946 base metal discoveries in Ontario are shown to be relatively small. On the other hand, earlier base metal finds in the shield region are large on average compared to the 1946-85 discoveries. This partly reflects the discovery prior to 1946 of multi-billion dollar deposits outside Ontario such as Horne in Quebec and Flin Flon in Manitoba. No base metal deposits of this calibre were found in Ontario at this time. For Canada overall, the 303 base metal discoveries made during the 1946-85 period are very much larger on average than the 102 deposits discovered before 1946. This difference primarily reflects the impact of huge porphyry copper and copper-molybdenum deposits discovered during the 1960s and 1970s.

The broad trends in average return characteristics of economic base metal deposits discovered before and during the study period are compared in table 28. None of the pre-1946 discoveries in Ontario would be economic for the current outlook conditions assumed in the evaluation. The superior size and profitability characteristics of economic base metal deposits found in the shield region prior to 1946 are evident. Economic deposits discovered in Canada during the 1946-85 period are of similar size but less profitable, on average, than the pre-1946 discoveries. The influence of the porphyry deposits is more modest here than in table 27, because relatively few of these discoveries would be economic for the current outlook conditions used in the appraisal.

Table 27

ONTARIO'S COMPETITIVE STANDING: TIME TRENDS IN AVERAGE BASE METAL ENDOWMENT CHARACTERISTICS FOR POSSIBLE ECONOMIC DISCOVERIES

	Discoveries in Ontario		Shield Region Discoveries		Discoveries in Canada	
	Pre-1946	1946-85	Pre-1946	1946-85	Pre-1946	1946-85
Possible economic discoveries (number)	12	34	43	148	102	303
Recoverable ore reserves (t million)	2	8	6	4	9	30
Annual mill capacity (t thousand)	143	335	337	282	461	1,342
Productive mine life (years)	8	10	11	10	10	12
Development capital cost ($ million)	28	40	43	45	46	84
Unit production cost ($/t)	107	75	92	99	91	73
Unit revenue ($/t)	72	65	75	75	108	67
Total revenue ($ million)	91	701	573	338	527	6[illegible]1

Table 28

ONTARIO'S COMPETITIVE STANDING: TIME TRENDS IN AVERAGE BASE METAL RETURN CHARACTERISTICS FOR ECONOMIC DISCOVERIES

	Discoveries in Ontario		Shield Region Discoveries		Discoveries in Canada	
	Pre-1946	1946-85	Pre-1946	1946-85	Pre-1946	1946-85
Economic discoveries (number)	0	9	11	41	31	104
Total revenue ($ million)	-	2,535	1,896	985	1,446	1,430
Net present value ($ million)	-	416	414	159	300	190
Rate of return (percent)	-	42	47	31	43	32

Time Trends

Table 29 shows time trends in the expected value of base metal and gold exploration combined in Ontario, the shield region, and Canada for the four decades within our 40-year study period. Similar comparative results are presented in table 30 for base metal exploration on its own and in table 31 for gold exploration.

The main findings can be summarized as follows:

- a marked deterioration is shown in the economics of base metal exploration in Ontario and throughout Canada in the 1966-75 interval and then more alarmingly in terms of the uneconomic performance assessed for the most recent 1976-85 interval;

- the economics of gold exploration, on the other hand, appear to be improving with time. The time trends presented in table 31 are somewhat tenuous, however, because a high proportion of the total activity is concentrated in the most recent decade;

- the individual base metal and gold trends tend to cancel out. The expected values for base metal and gold exploration combined shown in table 29, therefore exhibit more uniform, time trends. Base metal and gold exploration in Ontario, the shield region, and Canada remain economic through the entire study timeframe. Nevertheless, there is a noticeable deterioration in all three cases from the first two decades to the last two decades. Exploration activity is heavily concentrated in the second half of the study period. Total exploration expenditures in the last decade alone are of a similar magnitude to those made in the preceding 30 years;

- the time trends shown in tables 29-31 for Ontario, the shield region, and Canada are similar. This is partly due to overlap. Ontario is an important component of the shield region, and the shield region continues to be the most important exploration environment in Canada.

Table 29

ONTARIO'S COMPETITIVE STANDING: TIME TRENDS IN EXPECTED VALUES FOR MINERAL EXPLORATION

Region and Time Interval	Total Exploration Expenditures ($ million)	Number of Economic Discoveries	Average Explcration Expenditure (E,$ mill.)	Average Return (R,$ mill.)	Expected Value (EV,$ mill.)	Rate of Return (%)
Ontario:						
1946-55	93	5	16	94	78	18
1956-65	205	6	27	288	261	30
1966-75	357	7	36	51	15	11
1976-85	794	21	30	84	54	15
Shield Region:						
1946-55	294	19	12	50	38	18
1956-65	765	28	22	119	97	21
1966-75	1,033	21	36	64	28	12
1976-85	2,167	57	28	54	26	13
Canada:						
1946-55	416	31	12	117	105	23
1956-65	1,233	47	21	134	113	20
1966-75	2,460	43	39	80	41	12
1976-85	3,552	88	30	53	23	12

Table 30

ONTARIO'S COMPETITIVE STANDING: TIME TRENDS IN EXPECTED VALUES FOR BASE METAL EXPLORATION

Region and Time Interval	Total Exploration Expenditures ($ million)	Number of Economic Discoveries	Average Exploration Expenditure (E,$ mill.)	Average Return (R,$ mill.)	Expected Value (EV,$ mill.)	Rate of Return (%)
Ontario:						
1946-55	31	2	14	230	216	23
1956-65	149	2	46	489	443	23
1966-75	257	4	42	59	17	10
1976-85	305	1	74	1	-73	-2
Shield Region:						
1946-55	91	8	10	89	79	19
1956-65	625	11	39	148	109	16
1966-75	824	16	37	59	22	11
1976-85	920	6	63	11	-52	0
Canada:						
1946-55	226	20	10	174	164	25
1956-65	1,061	30	27	159	132	19
1966-75	2,165	35	41	81	40	12
1976-85	1,812	19	51	30	-21	5

Table 31

ONTARIO'S COMPETITIVE STANDING: TIME TRENDS IN EXPECTED VALUES FOR GOLD EXPLORATION

Region and Time Interval	Total Exploration Expenditures ($ million)	Number of Economic Discoveries	Average Exploration Expenditure (E,$ mill.)	Average Return (R,$ mill.)	Expected Value (EV,$ mill.)	Rate of Return (%)
Ontario:						
1946-55	62	3	18	10	-8	1
1956-65	56	4	12	25	13	17
1966-75	100	3	26	31	5	10
1976-85	489	20	20	104	84	21
Shield Region:						
1946-55	158	11	13	22	9	14
1956-65	140	17	8	72	64	26
1966-75	209	5	31	78	47	16
1976-85	1,247	51	20	66	46	18
Canada:						
1946-55	190	11	15	21	6	12
1956-65	172	17	9	70	61	24
1966-75	295	8	28	65	37	15
1976-85	1,740	69	21	62	41	18

Summing Up

The potential value of mineral exploration and mine development in Ontario is shown to be relatively high compared to more general results for the shield region and Canada. While discovery costs are remarkably similar, the economic deposits discovered in Ontario during the 1946-85 period are both larger and more profitable on average than those found in the rest of Canada. Ontario's strong competitive position is shown to be mainly attributable to the discovery of the Hemlo and Kidd Creek deposits within the province's boundaries.

A marked deterioration in the potential value of base metal exploration in Ontario and throughout Canada during the past 20 years is assessed, culminating in the uneconomic performance evaluated for 1976-85, the most recent decade analyzed. The rate of discovery has fallen, exploration costs have increased sharply, and the returns from economic discoveries have deteriorated. Consequently, the expected value of base metal exploration has become negative, indicating more money going "into the ground" in time-adjusted terms than coming out.

The potential value of gold exploration, on the other hand, appears to be improving with time in Ontario as well as elsewhere in Canada. This trend is somewhat tenuous, however, because so much of the activity is concentrated in the 1980s. Gold exploration expenditures during the decade 1976-85, for example, are of a similar magnitude to those made in the preceding 30 years.

7. MINING TAXATION CONSIDERATIONS

Chapters 4-6 have presented and analyzed results for the potential, before-tax value of base metal and gold exploration and development with particular reference to Ontario. It is now appropriate to evaluate what these assessments mean in terms of after-tax incentive to the mining company contemplating investment in mineral exploration and mine development.

For this purpose, the income and mining taxation systems operative in Ontario and more generally in Canada during 1987 are imposed on the potential value assessments, and measures of investment incentive are derived. A detailed description of the taxation systems applied is given in appendix VI. The three-year tax exempt period for Ontario mining tax introduced in 1987 is incorporated in the after-tax analysis.

Taxation Assumptions

Inflation

The existence of inflation complicates the evaluation of mining taxation effects. This is the result of two factors. First, the write-off of capital costs for tax purposes is only permitted over future periods of time. Tax allowances are taken against the current money income realized in those future time periods. Second, the amount which can be written off is limited to the actual capital costs incurred. Consequently, inflation reduces the real constant-money benefits of tax write-offs. Thus, inflation reduces investment incentive and increases government tax revenues in real terms. The higher the rate of inflation, the stronger these effects will be.

It is therefore important to consider inflation when assessing after-tax incentives for exploration and development. A 5-percent per year general rate of inflation is assumed here for this purpose.

Exploration Expenditures

The mining taxation systems outlined in appendix VI generally permit the "expensing" of exploration expenditures against current income as they are incurred.[11] This study does not consider the carry-forward of exploration expenditures for write-off against production income from economic deposits. Larger organizations are assumed to have sufficient income from other sources to be able to deduct exploration expenditures as they are incurred, receiving tax credits at the prevailing rate of taxation. Smaller enterprises are assumed to have no existing income, and therefore receive no direct tax benefit from their exploration expenditures. An equivalent tax credit can, however, be realized by the investors as a result of flow-through share policy.

The "base case" for the tax assessments assumes that 100 percent of the exploration expenditures are expensed for tax purposes. The effect of a 0-percent expensing variant is also considered. The rates that are used to calculate the tax credits realized on exploration expenditures are given at the end of appendix VI.

Development and Production Phase

Mining taxation allowances for the development and production phases can, generally speaking, be taken either on an individual project basis or on an integrated company basis. With the individual project basis of taxation, allowances for the development and production phases may only be taken against production income from the project. Thus, it is assumed that the mining company has no existing source of income. By "integrated company" we mean a mining company with existing sources of income from other projects. With the integrated company basis of taxation, allowances for the development and production phases may be written off as rapidly as possible against this existing income stream. The tax credits realized on an integrated company basis will, therefore, be more immediate than on an individual project basis.

---

[11]. When we say that exploration expenditures are "expensed" for tax purposes, we mean that they are deducted from a company's income in the year expended for purposes of computing taxable income. This, for example, is the same way that operating costs are treated for tax purposes.

The "base case" assumes that taxation is on an individual project basis. The integrated company basis of taxation is considered as a variant.

Base Case Results

The after-tax base case conditions, to which other results are compared, include those already specified in chapter 4 for the assessment of potential value. In addition, the following taxation conditions, discussed above, are embodied in the base case:

- 1987 Ontario and Canadian mining taxation systems;
- general rate of inflation of 5 percent;
- 100 percent of the exploration expenditures expensed for tax purposes;
- individual project basis of taxation for development and production phases.

For after-tax base case conditions, the number of economic deposits is reduced from 39 to 38. The cost and revenue characteristics of these 38 economic deposits are used to assess the time distribution of average after-tax cash flows for an economic deposit. These average cash flow results are presented in figure 18 and summarized in table 32. Thus, on average, the net after-tax cash flow associated with an economic deposit is $264 million as compared to $545 million before tax.

Table 33 presents after-tax expected value assessments for the base case conditions. As already mentioned, one deposit which represents a potentially economic exploration target is rendered uneconomic by the 1987 tax system. The average exploration expenditure required to find and delineate an economic deposit, $25 million potentially at the start of exploration, is reduced by the tax credits received to $11 million on an after-tax basis. However, the average return from an economic deposit is also reduced, from $109 million to $56 million. The $53 million difference in returns is the discounted equivalent of the time distribution of federal and Ontario taxation payments portrayed in figure 18. Thus, the after-tax expected value of base metal and gold exploration in Ontario per economic discovery is (56-11) = $45 million.

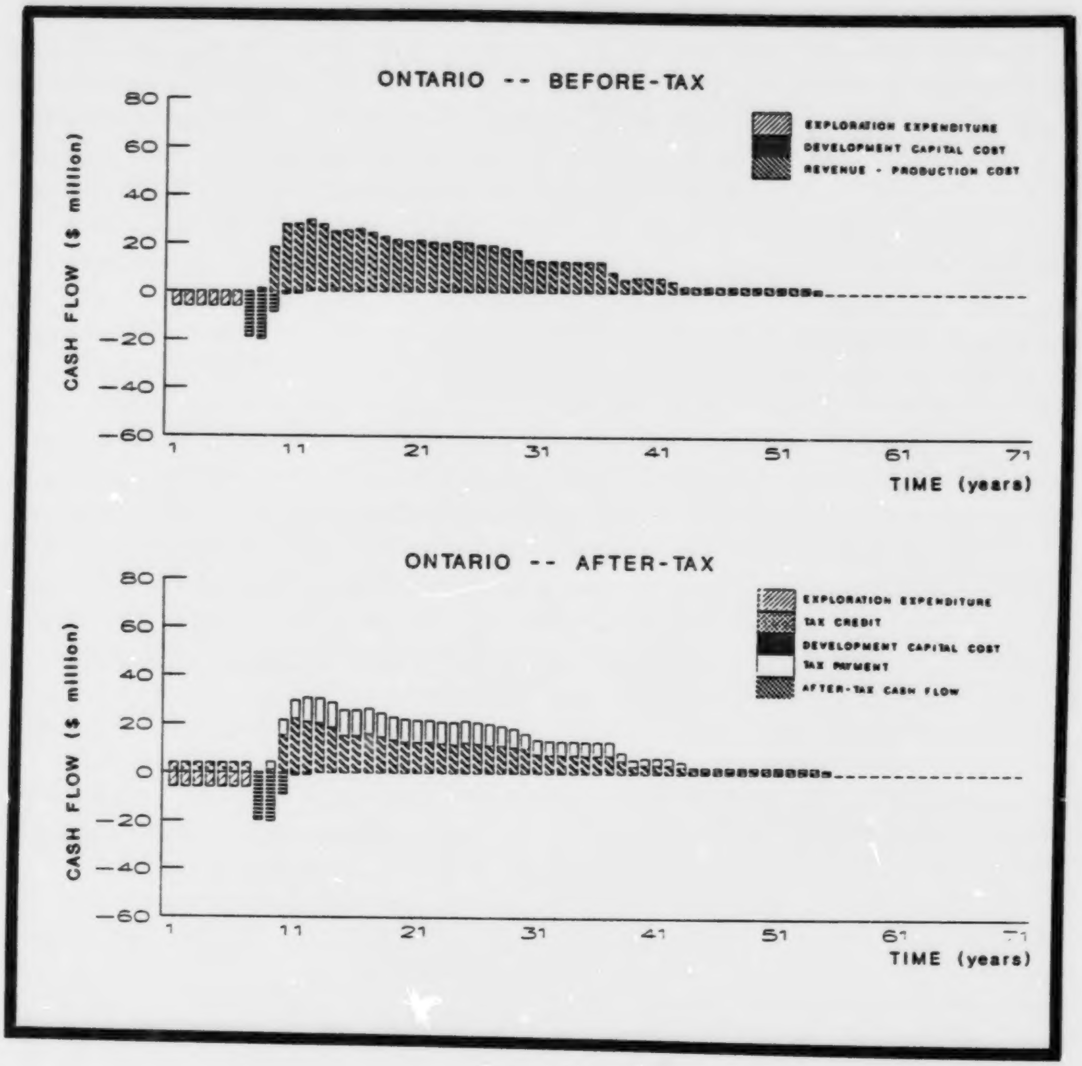


Figure 18. After-Tax Time Distribution of Average Cash Flows for an Economic Deposit: Base Case Conditions

The corresponding expected after-tax rate of return is shown in table 33 to be 19 percent as compared to the 18 percent potential rate of return. The rate of return increases after tax because at this discount rate the present value of exploration tax credits is greater than the present value of the tax liabilities incurred during production.

Table 32

AVERAGE AFTER-TAX CASH FLOW CHARACTERISTICS FOR AN ECONOMIC DEPOSIT UNDER BASE CASE CONDITIONS

	Ontario	
Characteristic	Potential Value	After-Tax Value
Time periods (years)		
Exploration phase	6	7
Development phase (maximum)	5	5
Production phase (maximum)	47	47
Undiscounted values ($ million):		
Revenue	985	1,011
Exploration expenditure	38	39
Development capital cost	50	51
Production cost	352	361
Tax and royalty payments		246
Cash flow	545	264

Table 33

AFTER-TAX EXPECTED VALUES FOR MINERAL EXPLORATION IN ONTARIO UNDER BASE CASE CONDITIONS

	Ontario	
Category	Potential Value	After-Tax Value
Number of economic discoveries	39	38
Average exploration expenditure (E, $ million)	29	11
Average return (R, $ million)	109	56
Expected Value (EV, $ million)	80	45
Rate of return (percent)	18	19
Share of actual value (percent)		
Mining company's		56
Governments'		44

The level or incidence of taxation can be illustrated by the relationship between the present value of the net tax payments and the present value of after-tax cash flows, both discounted at the 8-percent cost of capital. The sum of these two components is termed the "actual value" of mineral supply, as compared to the "potential value" assessed in chapters 4-6.

In Ontario under base case conditions, government taxation payments are shown in table 33 to represent about 44 percent of the actual value yielded by economic deposits. Consequently, mining companies receive 56 percent of the actual value realized in the form of after-tax cash flows.

Turning now to the economics of mine development, after-tax assessments for the development and production phases of the cash flow distribution illustrated in figure 18 are shown in table 34. The expected net present value per economic deposit is reduced from $177 million to $42 million, and the expected rate of return falls from 46 percent to 35 percent. The mining company's share of the actual value realized is 51 percent. The Ontario and federal governments receive the remaining 49 percent in taxation payments. The mining company's share at the start of development is lower than its share at the start of exploration (51 percent versus the 56 percent shown in table 33) because the exploration-phase tax credits are no longer a relevant consideration for evaluation purposes.

Table 34

AFTER-TAX EXPECTED VALUES FOR MINE DEVELOPMENT IN ONTARIO UNDER BASE CASE CONDITIONS

	Ontario	
Category	Potential Value	After-Tax Value
Net present value ($ million)	177	92
Rate of Return (percent)	46	35
Share of actual value (percent)		
Mining company's		51
Governments'		49

Metal Price Variants

The after-tax assessment of expected values for base metal and gold exploration in Ontario as a function of metal price is summarized in table 35. The value of mineral exploration remains decidedly uneconomic at lower-limit prices with the loss being shared through the tax system by industry and government. The enhanced expected values at upper-limit prices are somewhat eroded by the higher incidence of taxation payments shown, the governments' share of the actual value realized increasing from 44 percent to 46 percent.

Ontario's Competitive Standing

After-tax expected values for base metal and gold exploration in Ontario, the shield region, and Canada are compared in table 36. Similarly, the after-tax economics of mine development are presented in table 37.

Ontario's competitive position is improved on an after-tax basis with respect to both mineral exploration and mine development. The governments' share of the actual value realized in Ontario is in both cases shown to be somewhat smaller than the collective average for the other Canadian jurisdictions. Ontario's taxation policies are also shown to be more efficient. A greater proportion of the potential economic discoveries remain economic on an after-tax basis: 97 percent as compared to 95 percent in the shield region and 93 percent for Canada overall.

Tax Write-Off Variants

The effects of the following three sets of exploration and development tax write-off provisions are considered here.

1. Base Case Conditions: 100-percent expensing of exploration expenditures; individual project basis of taxation.

2. Tax Variant 1: 0-percent expensing of exploration expenditures; individual project basis of taxation.

Table 35

AFTER-TAX EXPECTED VALUES FOR MINERAL EXPLORATION IN ONTARIO AS A FUNCTION OF METAL PRICE

	Lower-Limit Prices		Expected Prices		Upper-Limit Prices	
	Potential Value	After-Tax Value	Potential Value	After-Tax Value	Potential Value	After-Tax Value
Number of economic discoveries	7	6	39	38	48	48
Average exploration expenditure (E, $ million)	10	26	29	11	25	9
Average return (R, $ million)	11	3	109	56	202	105
Expected value (EV, $ million)	-59	-23	80	45	177	96
Rate of return (percent)	3	3	18	19	28	30
Share of actual value (percent)						
Mining company's		35[a]		56		54
Governments'		65[a]		44		46

[a] in this case the negative potential value (a loss) is being shared.

Table 36

ONTARIO'S COMPETITIVE STANDING: AFTER-TAX EXPECTED VALUES FOR MINERAL EXPLORATION

	Ontario		Shield Region		Canada	
	Potential Value	After-Tax Value	Potential Value	After-Tax Value	Potential Value	After-Tax Value
Number of economic discoveries	39	38	125	119	209	194
Average exploration expenditure (E, $ mill.)	29	11	26	11	28	11
Average return (R, $ mill.)	109	56	69	37	85	41
Expected value (EV, $ mill.)	80	45	43	26	57	30
Rate of return (%)	18	19	15	16	15	15
Share of actual value (%)						
Mining company's		56		58		53
Governments'		44		42		47

Table 37

ONTARIO'S COMPETITIVE STANDING: AFTER-TAX EXPECTED VALUES FOR MINE DEVELOPMENT

	Lower-Limit Prices		Expected Prices		Upper-Limit Prices	
	Potential Value	After-Tax Value	Potential Value	After-Tax Value	Potential Value	After-Tax Value
Return per economic deposit ($ mill.)	177	92	107	58	135	68
Rate of return (%)	46	35	39	30	32	25
Share of actual value (%)						
Mining company's		51		51		48
Governments'		49		49		52

3. Tax Variant 2: 100-percent expensing of exploration expenditures; integrated company basis of taxation.

Results are presented in table 38. The ability to expense exploration costs for tax purposes is a great advantage, as illustrated by differences between the base case and variant 1 in the average exploration expenditure (E) and by differences in the company/government shares of the actual value realized. Surprisingly, there is only a modest difference between the results for the individual project and integrated company tax bases (the base case and variant 2).

Generally, there is a marked inequality between the traditional tax treatment of junior exploration enterprises (variant 1) and established mining companies (variant 2), as shown in table 36 by the comparative expected values per economic discovery (EV) and expected rates of return. A benefit of flow-through share policy is that it effectively closes this discriminatory gap.

Effect of the Three-Year Tax Exempt Period

The effect of the three-year tax exempt period for Ontario mining tax on the after-tax expected values of mineral exploration is presented in table 39. Similarly, table 40 shows results for the after-tax economics of mine development in Ontario.

The tax exempt period is found to offer significant benefits in terms of increasing the number of economic discoveries, improving the expected values of mineral exploration and mine development, and enhancing the mining companies' share of the actual value realized.

Inter-Provincial Comparison

In order to compare the effects of taxation in Ontario with those which characterize the other Canadian provinces and territories, the 1987 tax system in each jurisdiction (appendix VI) is applied in turn to Ontario's before-tax mineral exploration potential. Results are presented in table 41.

Table 38

AFTER-TAX EXPECTED VALUES FOR MINERAL EXPLORATION IN ONTARIO AS A FUNCTION OF TAX WRITE-OFF VARIANTS

	Ontario	
Category and Tax Variant	Potential Value	After-Tax Value
Number of economic discoveries	39	
Base case		38
Tax variant 1		38
Tax variant 2		40
Average exploration expenditure (E, $ mill.)	29	
Base case		11
Tax variant 1		30
Tax variant 2		10
Average return (R, $ mill.)	104	
Base case		56
Tax variant 1		56
Tax variant 2		56
Expected value (EV, $ mill.)	80	
Base case		45
Tax variant 1		26
Tax variant 2		36
Rate of return (%)	18	
Base case		19
Tax variant 1		12
Tax variant 2		21
Mining company/government shares (%)		
Base case		56/44
Tax variant 1		33/67
Tax variant 2		59/41

Table 39

AFTER-TAX EXPECTED VALUES FOR MINERAL EXPLORATION IN ONTARIO: EFFECT OF THE THREE-YEAR TAX EXEMPT PERIOD

	Potential Value	After-Tax Value	
		Without Tax Exempt Period	With Tax Exempt Period
Number of economic discoveries	39	35	38
Average exploration expenditure (E, $ mill.)	29	11	11
Average return (R, $ mill.)	109	52	56
Expected value (EV, $ mill.)	80	41	45
Rate of return (%)	18	18	19
Share of actual value (%)			
Mining company's		49	56
Governments'		51	44

Table 40

AFTER-TAX EXPECTED VALUES FOR MINE DEVELOPMENT IN ONTARIO: EFFECT OF THE THREE-YEAR TAX EXEMPT PERIOD

	Potential Value	After-Tax Value	
		Without Tax Exempt Period	With Tax Exempt Period
Net present value ($ million)	177	85	92
Rate of return (%)	42	32	35
Share of actual value (%)			
Mining company's		46	51
Governments'		54	49

Table 41

ONTARIO'S COMPETITIVE STANDING: INTER-PROVINCIAL COMPARISON OF AFTER-TAX VALUES

	Number of Economic Discoveries	Average Exploration Expenditure (E,$ mill.)	Average Return (R,$ mill.)	Expected Value (EV,$ mill.)	Rate of Return (%)	Share of Actual Value (%)	
						Mining Company's	Governments'
Potential Values	39	29	109	80	18		
After-Tax Values:							
Ontario	38	11	56	45	19	56	44
Newfoundland	35	11	51	40	18	49	51
Nova Scotia	37	11	56	45	19	56	44
New Brunswick	38	8	51	43	20	54	46
Quebec	36	13	60	47	18	57	43
Manitoba	36	12	53	41	19	50	50
Saskatchewan	34	12	57	45	18	54	46
Alberta	38	13	61	48	19	60	40
British Columbia	35	11	50	39	18	47	53
Northwest Territories	38	15	63	48	18	60	40
Yukon Territory	38	15	61	46	18	57	43

The effects of Ontario's taxation policies tend to rank towards the middle of the spectrum of inter-provincial assessments, summarized as follows:

- the number of discoveries which would be economic after tax varies from 34 to 38, including 38 for Ontario and four other regimes;
- the average after-tax exploration expenditure per economic discovery ranges from $8 million to $15 million, including $11 million for Ontario;
- the average after-tax return from an economic deposit varies from $50 million to $63 million, including $56 million for Ontario;
- the after-tax expected value of exploration per economic discovery ranges from $39 million to $48 million, including $45 million for Ontario;
- the after-tax rate of return on investment varies from 18 percent to 20 percent, including 15 percent for Ontario;
- the mining company's share of the actual value realized from mineral exploration ranges from 47 percent to 60 percent, including 56 percent for Ontario;
- conversely, the governments' share varies from 40 percent to 53 percent, including 44 percent for Ontario.

The comparative incidence of taxation in the eleven jurisdictions can be measured by the present value of total tax payments, expressing payments in the ten other jurisdictions relative to an index of 100 for the present value of total taxes associated with the policies currently operative in Ontario. The resulting tax indices are presented in figure 19. The level of mining taxation in Ontario is found to be:

- significantly lower than in British Columbia, Manitoba, Newfoundland, and Saskatchewan;
- about the same as in Quebec and New Brunswick;

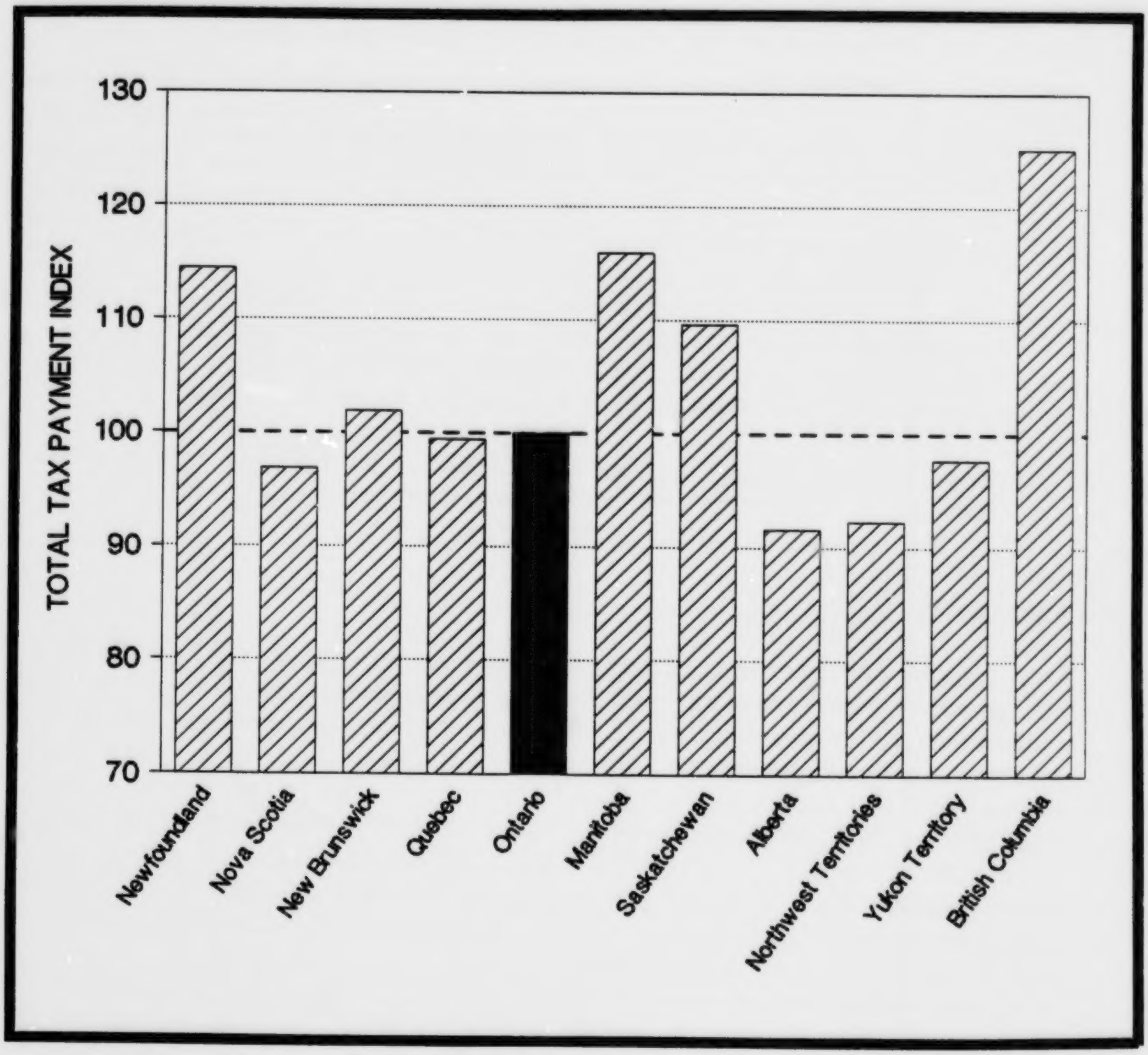


Figure 19. Inter-Provincial Comparison of Total Tax Payments: Ontario's Competitive Standing

- somewhat higher than in Alberta, the Northwest Territories, Nova Scotia, and the Yukon.

Ontario's competitive tax position for each of the three components which make up this composite picture - federal corporate income tax, provincial corporate income tax, and provincial mining tax - is illustrated in figure 20. The main findings can be summarized as follows:

- federal corporate income tax payments are similar for all jurisdictions with the exception of the three maritime provinces where the investment tax credit is still operative, giving a noteworthy degree of relief;

- Ontario corporate income tax payments are shown in figure 20 to be significantly lower than in British Columbia and, on the other hand, significantly higher than in Quebec, the Yukon Territory, the Northwest Territories, and Alberta;[12]

- the Ontario mining tax system is shown to be very competitive among the Canadian jurisdictions.

Summing Up

The impact of taxation in Ontario on the incentive for investment in mineral exploration and mine development is shown to be substantial. For example, in the base case, the expected value of exploration per economic discovery is reduced from a potential value of $80 million to $45 million on an after-tax basis. Similarly, the expected net present value associated with mine development decreases from $177 million to $92 million after tax. Tax payments are found to represent 44 percent of the actual value realized from mineral exploration and 49 percent of the corresponding figure for mine development.

The after-tax effects of Ontario's taxation policies are shown to be sensitive to future metal price levels, the degree to which exploration costs can be expensed for tax purposes, and whether the taxation of the development and production phases of mineral supply is on an individual-project or an integrated-company basis.

---

[12]. The small variations in federal tax payments shown in figure 20 from Quebec to British Columbia arise because of differences in the number of discoveries which would be economic (see table 41).

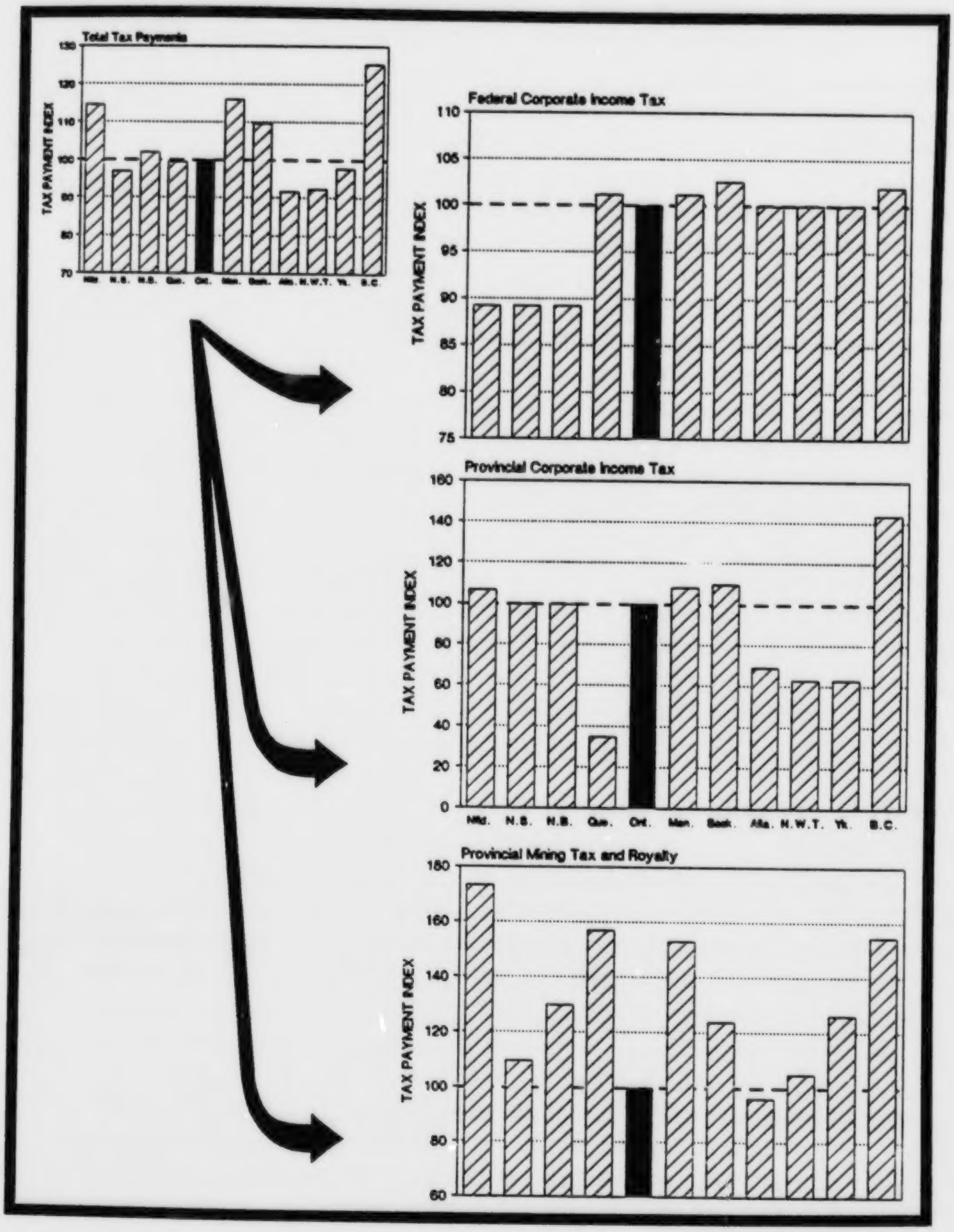


Figure 20. Inter-Provincial Comparison of Tax Payments by Component: Ontario's Competitive Standing

The three-year tax exempt period for Ontario mining tax introduced in 1987 is found to have a significant beneficial effect on the after-tax incentive for investment in exploration and development. For example, without this incentive the after-tax expected value per economic discovery would be $41 million and the after-tax net present value of mine development would average $85 million, as compared to $45 million and $92 million respectively with this new policy measure.

The effects of Ontario's taxation system tend to rank towards the middle of the Canadian league of provinces and territories. The overall incidence of taxation in Ontario is shown to be significantly lower than in British Columbia, Manitoba, Newfoundland, and Saskatchewan; about the same as in Quebec and New Brunswick; and somewhat higher than in Alberta, the Northwest Territories, Nova Scotia, and the Yukon Territory. While federal and provincial corporate income taxes in Ontario tend to be on the high side, Ontario is found to be in a strong competitive position with respect to provincial mining tax.

8. CONCLUSION

The economic potential of mineral exploration and mine development in Ontario has been assessed and compared. The results for base metal and gold supply have been analyzed with a view to providing guidelines for public policy formulation.

The economic characteristics appraised in the study provide a factual record of the mineral supply process as it has evolved in Ontario since the second world war. Having evaluated this historical experience in terms of current outlook conditions, the results can be applied when looking ahead to estimate both the requirements for and the consequences of government policy.

The assessments of economic potential are intended to illustrate several important and sometimes neglected features of mineral exploration and mine development with particular reference to Ontario.

1. Mineral deposits are the focal point of mineral exploration and mine development. Therefore, they are the building blocks we should use for economic analysis of the mineral supply process. For example, the present study is based on the 70 significant base metal and gold deposits discovered in Ontario during the 46-year period 1946-85.

2. A composite profile of an economic mineral deposit can be synthesized from the characteristics of all economic deposits. This is illustrated by the assessment made for 39 of the 70 discoveries in Ontario which are found to be economic for anticipated future conditions. This type of representative profile is a useful way of summarizing the potential value of exploration and development, and measuring the direct effects of government policy.

3. The mineral supply process is particularly sensitive to future economic conditions and to government policies because of the high degree of variability in potential which exists among individual mineral deposits. For example, a 100-times difference is shown in net present value between the lower-decile and upper-decile statistics for the 39 economic base

metal and gold deposits evaluated in Ontario. Economic variability of this magnitude, a reflection of underlying differences in geological parameters, can be taken into account for policy analysis by examining all significant deposits which have been discovered.

4. The high degree of variability which exists among individual mineral deposits is attributable in part to the presence of a few multi-billion dollar discoveries. These exceptional finds have a profound effect on the economic potential of mineral exploration and mine development. This is illustrated in the present study by the Kidd Creek and Hemlo deposits. These two deposits, among the 39 economic deposits evaluated, are found to make the difference between Ontario being a province with high prospects for exploration investment and what would otherwise be a marginal environment on average. Thus, the effect of such deposits on provincial assessments and the potential for future world-class discoveries need to be carefully examined.

5. The mineral supply process starts with the search for economic deposits. In the long term, the economic potential of mineral supply has to include the exploration activity required as a prerequisite for mine development. This up front activity is portrayed in the study by the $37 million and six years required on average to find and delineate an economic deposit in Ontario.

6. While mineral exploration and mine development are integral parts of the mineral supply process, their economic characteristics are quite different and should be clearly distinguished. For anticipated future conditions in Ontario, this distinction is illustrated by the $80-million expected value of an economic deposit assessed at the start of exploration as compared to the average value of $177 million appraised at the start of mine development. The $97-million enhancement in potential value which occurs in this case reflects exploration's economic contribution to the mineral supply process.

7. When historical experience is documented and analyzed with a view to providing future planning guidelines, it is important to examine possible time trends. According to the evaluation procedure employed here, time trends measure the interplay of depletion effects and advances in geological concepts and exploration technology. One of the significant study findings is the marked deterioration in the potential value of base metal exploration which has occurred in Ontario and throughout Canada during the past 20 years. Further examination and explanation of this disturbing result should be undertaken.

8. Relative measures of economic performance provide useful standards in a competitive world, particularly because their validity is not so dependent on the uncertainties associated with absolute measurement of mineral supply potential. In the present study, for example, Ontario's competitive standing is evaluated by making similar but more general appraisals of economic potential for the shield region and for Canada.

9. Assessment of the economic potential of mineral supply provides a basis for evaluating the direct effects of government mineral policies. For this purpose, appropriate policy regimes are imposed on the potential value assessments, and measures of policy efficiency, investment incentive, and government revenue are derived. This type of policy application is illustrated here by analyzing the effects of the current income and mining taxation systems operative in Ontario and more generally in Canada. The sensitivity of results to the three-year tax exempt period for Ontario mining tax introduced in 1987 is examined. The effects of taxation in Ontario are compared with those which characterize ten other Canadian jurisdictions, showing another aspect of competitive position.

It is costly and ineffective to approach each mineral policy issue on an ad hoc basis. The data base, evaluation procedure, and economic assessments illustrated in this study for mineral exploration and mine development in Ontario are designed to provide a more efficient and sustainable on-going capability. We recommend that the Ontario government consider adopting this type of approach to support mineral policy formulation and decision-making.

APPENDICES

APPENDIX I

INFLATION MULTIPLIER SERIES USED IN STUDY

The inflation multiplier, derived from the Gross Domestic Product (GDP) Inlplicit Price Index, is used to convert historical current-dollar statistics to 1987-dollar equivalents.

Year	GDP Implicit Price Index (1981 = 100)	Change From Previous Year (percent)	Inflation Multiplier (1987 = 1.000)
1946	17.1		7.620
1947	18.8	9.9	6.931
1948	21.2	12.8	6.146
1949	22.1	4.2	5.896
1950	22.6	2.3	5.765
1951	25.2	11.5	5.171
1952	26.2	4.0	4.973
1953	26.2	0.0	4.973
1954	26.6	1.5	4.898
1955	26.8	0.8	4.862
1956	27.8	3.7	4.687
1957	28.4	2.2	4.588
1958	28.8	1.4	4.524
1959	29.4	2.1	4.432
1960	29.7	1.0	4.387
1961	29.9	0.7	4.358
1962	30.3	1.3	4.300
1963	30.9	2.0	4.217
1964	31.7	2.6	4.110
1965	32.8	3.5	3.973
1966	34.4	4.9	3.788
1967	35.8	4.1	3.640
1968	37.1	3.6	3.512
1969	38.8	4.6	3.358
1970	46.6	4.6	3.209
1971	41.9	3.2	3.110
1972	44.3	5.7	2.941
1973	48.2	8.8	2.703
1974	55.1	14.3	2.365
1975	60.6	10.0	2.150

APPENDIX I (continued)

Year	GDP Implicit Price Index (1981 = 100)	Change From Previous Year (percent)	Inflation Multiplier (1987 = 1.000)
1976	65.8	8.6	1.980
1977	69.9	6.2	1.864
1978	74.2	6.2	1.756
1979	81.6	10.0	1.597
1980	90.2	10.5	1.445
1981	100.0	10.9	1.303
1982	108.7	8.7	1.199
1983	114.1	5.0	1.142
1984	118.0	3.4	1.104
1985	121.7	3.1	1.071
1986	125.3	3.0	1.040
1987	130.3	4.0	1.000

Source:

1947-86: prepared by Karen Wilson, Income and Expenditure Accounts Division, Statistics Canada.
1946: estimated from the relationship with the consumer price index (CPI) for the 1947-51 period as follows -
average (GDP/CPI) for 1947-51 = 0.90;
CPI for 1946 = 19.0;
estimated GDP index for 1946 = 19.0(.90) = 17.1.
1987: preliminary estimate based on January-September.

APPENDIX II

EXPLORATION EXPENDITURE ESTIMATES

Mineral exploration expenditures are based on data collected by Statistics Canada (STCAN, Dominion Bureau af Statistics, DBS, prior to 1969) from mining and exploration companies. These data are grouped by province and territory and, until 1963, by commodity group. After 1963, proportions of the provincial expenditure totals are broken out to represent individual commodities. Exploration expenditures for three commodity groups are pertinent to this study: total metallic minerals; base metals (copper, lead, zinc, molybdenum); and gold. In order to derive these series, it is necessary to first deduct non-metallic exploration expenditures and then non-study metallic mineral expenditures from STCAN provincial totals.

Once the commodity breakdowns by province have been determined, they can be grouped into specific exploration environments. For the present study, the shield region is of interest.

Metallic Mineral Exploration

Canada

Estimates of non-metal exploration expenditures have been deducted from the overall exploration expenditures described above to obtain a series representing total metallic mineral exploration expenditures for Canada from 1946-85. This series is shown in table 42. These expenditures represent total "cost of prospecting by metal mining companies" as given by DBS for the period 1946-67. From 1965-85, the expenditures reflect STCAN values for both on-property and off-property metallic mineral exploration. For the sake of continuity, figures in some years have been altered to reflect changes in the format and content of the STCAN series over time. Furthermore, the provincial totals for metallic mineral exploration supplied by STCAN are sometimes smaller than corresponding values obtained by summing the commodity breakdowns supplied by other sources. This problem arises particularly in cases where one metal accounts for a large proportion of total metallic expenditures, as was the case for uranium in Saskatchewan in the 1970s and for nickel in Manitoba in the early 1950s. When this situation occurs both the STCAN provincial totals and the Canadian totals have been increased proportionately.

Ontario

Total metallic mineral exploration expenditures for Ontario are shown in table 43. Values for the 1946-67 period are based on DBS figures for total exploration by metal mining companies. The DBS breakdown by commodity groupings reveals lower values for certain metals than those indicated from other sources. In these cases the annual totals have been increased to reflect the higher values. For example, the expenditures for both uranium and nickel exploration are not fully covered by DBS in the mid-1950s. More complete provincial government and industry sources have been used to represent these values. As a result the provincial total for metallic mineral exploration has been proportionately increased.

From the 1968-85 period, total metallic exploration expenditures in Ontario are based on STCAN and EMR values for total on-property and off-property expenditures less any non-metal exploration expenditures. The STCAN values for Ontario for several years during the period appear to be incomplete as evidenced by large decreases in exploration expenditures which do not occur in other provinces. In these cases, subjective estimates have been made to bring the level of expenditures in line with the overall trends.

Exploration for Non-Study Metals

In order to derive exploration expenditure series for the commodities examined in this study (gold and base metals), expenditures for non-study metals must be deducted from total metallic mineral exploration expenditures as described above. The non-study metals comprise four commodity groupings: nickel, uranium, iron ore, and "others".

Nickel exploration expenditure estimates are based on Inco and Falconbridge nickel exploration expenditures by year and by province over the 1951-85 period, subjective estimates of nickel exploration expenditures by other organizations, and DBS data for nickel-copper mines for 1946-63.

Uranium exploration expenditure estimates for the period 1946-65 are based on a synthesis of published estimates, data obtained from a number of provincial and federal government sources, and subjective estimates by exploration personnel. From 1975-85, estimates reflect published figures from provincial governments in Saskatchewan and Quebec, as well as values obtained through surveys of the uranium industry by URAG.

It is difficult to obtain reliable information on iron ore exploration expenditures in Canada over the study period. Subjective estimates based on provincial and federal government reports form the basis of the iron ore series in the early years of the study. For 1975-85, data are more complete because of better figures from provincial governments and the beginning of detailed commodity breakdowns for exploration expenditures by EMR.

"Other" metals include tin, tungsten, chromite, niobium, platinum group and other less important metals. Exploration expenditures for this category are small in most years and are based on subjective estimates from a combination of provincial and federal government as well as mining company sources.

Gold Exploration

Canada

Deducting the exploration expenditures for non-study metals from those for total metallic minerals leaves the values for gold and base metals. To complete the commodity breakdown, gold exploration expenditures have been separated as shown in table 42.

From 1946-63, only exploration by gold mining companies was classified by DBS as gold exploration. Other companies were considered not to have explored for gold and gold mining companies were assumed to have looked only for gold. While this was not strictly the case, we assume that exploration by gold mining companies for other metals was offset by exploration expenditures of other companies searching for gold.

Estimates for gold exploration from 1964-74 are based on subjective estimates of federal and provincial governments and exploration personnel.

From 1975, the Statistics Canada questionnaire sent to exploration and mining companies asks for breakdowns of exploration expenditures by commodity and province. Estimates of total gold expenditures in each province are based on totals obtained when individual company expenditures for gold are totalled. This is done for the years 1975, 1977, 1979, 1981, 1983, and 1985. Values for years in which disaggregated data are missing during the 1975-85 interval are estimated by interpolating between the values for adjacent years.

Ontario

Gold exploration expenditure estimates in Ontario for the 1946-85 period are shown in table 43. These estimates are based on the same criteria as described above for Canadian gold exploration. DBS values are used for the 1946-67 period while subjective estimates cover the 1968-74 periods. From 1975-85, gold exploration expenditures reflect EMR compilations of STCAN individual company exploration expenditures for gold. Actual figures have been supplied for the years 1975, 1977, 1979, 1981, 1983, and 1985. The remaining years during this period have been estimated by interpolating between values for adjacent years.

Base Metal Exploration

Canada

The process of deducting exploration expenditures for all other metals from the value for total metallic mineral exploration expenditures has left a residual which represents expenditures for base metal exploration. For the purposes of this study, the base metals group comprises copper, lead, zinc and molybdenum. Base metal exploration expenditures for Canada during the 1946-85 period are shown in table 42.

In a few cases, the residual value for a particular province in a particular year was obviously either too high or too low in relation to the overall series. In these instances, the values have been changed on the basis of subjective estimates of government and mining company sources.

For 1985, base metal exploration expenditures have been derived by deducting estimates for nickel exploration from the value for base metal exploration reported by EMR.

Ontario

Base metal exploration expenditures for Ontario are shown in table 43. These values have been determined using the residual process as described above with the exception of 1985 where the value reflects EMR estimates of the sum of individual companies' base metal exploration expenditures during that year.

Exploration in the Shield Region

Canada can be divided into four broad geologic regions or exploration environments. These are the appalachian, shield, cordilleran and other regions. The shield region has been isolated here to provide a comparison with the province of Ontario and the rest of Canada. Exploration expenditures for gold and base metals in the shield region are presented in table 44. The shield region comprises parts of the provinces of Ontario, Quebec, Manitoba, Saskatchewan, Newfoundland and the Northwest Territories. The shield portion of the Northwest Territories extends as far west as the Great Slave Lake - Great Bear Lake region, where the interior platform region begins. In Quebec, the area north of the St. Lawrence River is considered to be part of the shield, while in Newfoundland, Labrador is considered as part of the shield region.

Constant Dollar Exploration Expenditures

To examine real constant dollar trends in exploration expenditures, inflationary effects have to be removed from the current dollar series presented in tables 42-44. Since the purchasing power of a dollar is assumed to remain constant, some year (1987 in this case) is specified to define the constant money base. The current dollar expenditures are converted to constant 1987 dollars using the inflation multiplier series derived from the Gross Domestic Product (GDP) Implicit Price Index for Canada in appendix I.

Table 45 shows total metallic, gold and base metal expenditures in Canada in constant 1987 dollars. Tables 46 and 47 show similar breakdowns for Ontario and the shield region respectively. These estimates are used for study purposes as summarized in table 1 in the text.

Exploration Expenditure Data Sources

BCP	British Columbia provincial government mining reports.
BMK	Saskatchewan uranium expenditures provided by Bruce McKnight.
CMY	Canadian Minerals Yearbook.
DBS	Dominion Bureau of Statistics (becomes Statistics Canada, STCAN, after 1968).
DC	Federal government data and estimates provided by Donald Cranstone.
DIAND	Department of Indian and Northern Affairs, Ottawa.
EMR	Energy, Mines and Resources Canada.
FALC	Falconbridge Limited.
HBM&S	Hudson Bay Mining and Smelting Limited.
INCO	Inco Limited.
NFP	Newfoundland provincial government data provided by John Fleming and Ken Andrews.
NSP	Nova Scotia provincial government data.
QP	Quebec provincial government data from "Statistiques sur l'investissement de l'industrie minerale du Quebec".
SCORE	Ontario provincial government data from "Ontario Mineral SCORE".
SP	Saskatchewan provincial government data provided by Philip Reeves.
STCAN	Statistics Canada (DBS prior to 1969).
URAG	Uranium Resource Appraisal Group; Energy, Mines and Resources Canada.

TABLE 42

EXPLORATION EXPENDITURES IN CANADA
($ current thousand)

Year	Total Metallic Minerals	Base Metals	Gold	Base Metals and Gold
1946	9,316	1,313	6,420	7,733
1947	7,460	777	4,187	4,964
1948	5,815	1,490	2,501	3,991
1949	7,258	1,777	3,211	4,988
1950	7,678	2,223	2,756	4,979
1951	11,742	2,354	2,414	4,768
1952	18,036	4,013	2,566	6,579
1953	22,063	6,712	2,573	9,285
1954	32,250	10,447	3,400	13,847
1955	34,744	12,741	1,461	14,202
1956	57,608	23,703	4,265	27,968
1957	65,439	29,940	3,372	25,312
1958	45,703	13,486	2,247	15,733
1959	57,124	25,853	3,648	29,501
1960	48,314	25,338	3,815	29,153
1961	47,028	25,997	3,663	29,600
1962	47,323	23,638	4,994	28,632
1963	44,422	22,880	4,706	27,586
1964	50,929	31,625	4,279	35,904
1965	57,467	30,489	4,595	35,084
1966	72,652	43,782	4,971	48,753
1967	75,614	46,404	5,502	51,906
1968	104,113	65,080	8,092	73,172
1969	136,850	85,963	10,829	96,792
1970	152,683	97,906	11,100	109,006
1971	126,537	76,514	9,353	85,867
1972	104,180	67,219	6,812	74,031
1973	118,673	75,784	11,379	87,163
1974	130,073	78,185	13,960	92,145
1975	150,823	80,842	19,773	100,615
1976	169,159	83,412	18,394	101,806
1977	221,011	96,924	26,662	123,586
1978	258,877	86,038	36,631	122,669
1979	324,194	118,173	49,201	167,374
1980	478,273	195,197	104,956	300,153
1981	546,834	119,577	176,581	406,158
1982	416,863	140,290	185,661	325,351
1983	377,179	116,289	198,404	314,693
1984	464,080	131,775	273,494	405,269
1985	496,487	92,636	353,870	446,506

TABLE 43

EXPLORATION EXPENDITURES IN ONTARIO
($ current thousand)

Year	Total Metallic Minerals	Base Metals	Gold	Base Metals and Gold
1946	3,102	103	2,036	2,139
1947	1,742	63	1,242	1,305
1948	1,147	122	723	845
1949	1,418	150	866	1,016
1950	1,784	158	887	1,045
1951	4,185	256	986	1,242
1952	4,718	146	926	1,072
1953	7,537	402	831	1,233
1954	11,388	1,973	1,232	3,205
1955	15,231	2,881	790	3,671
1956	18,491	4,507	1,214	5,721
1957	21,185	3,939	1,481	5,420
1958	10,636	1,678	850	2,528
1959	8,661	3,305	1,203	4,508
1960	11,066	3,931	915	4,846
1961	9,082	3,188	1,164	4,352
1962	9,408	2,096	1,800	3,896
1963	8,476	2,332	1,062	3,394
1964	13,300	5,810	1,596	7,406
1965	14,300	3,568	1,716	5,284
1966	13,400	1,321	1,608	2,929
1967	17,236	5,095	2,068	7,163
1968	24,480	7,076	2,938	10,014
1969	30,912	11,333	3,709	15,042
1970	41,184	18,791	4,942	23,733
1971	28,800	8,172	3,456	11,628
1972	20,352	5,856	2,442	8,298
1973	24,384	8,533	3,658	12,191
1974	25,632	7,486	3,845	11,331
1975	30,336	12,659	4,913	17,572
1976	33,216	13,734	6,948	20,682
1977	38,688	16,970	8,983	25,953
1978	27,648	10,550	9,803	20,353
1979	33,408	15,082	10,621	25,703
1980	69,188	34,853	24,781	59,634
1981	95,452	46,875	38,940	85,815
1982	86,240	24,270	57,449	81,719
1983	98,490	16,817	75,960	94,777
1984	111,500	25,184	81,903	106,277
1985	102,456	12,613	86,225	98,838

TABLE 44

EXPLORATION EXPENDITURES IN THE SHIELD REGION
($ current thousand)

Year	Base Metals	Gold	Base Metals and Gold
1946	998	5,602	6,600
1947	509	3,414	3,923
1948	885	2,110	2,995
1949	833	2,617	3,450
1950	698	2,186	2,884
1951	1,137	2,037	3,174
1952	1,847	1,960	3,807
1953	1,809	1,947	3,756
1954	3,637	2,972	6,608
1955	6,320	1,170	7,490
1956	13,576	3,237	16,813
1957	14,092	2,691	16,784
1958	8,039	1,709	9,748
1959	18,860	3,086	21,946
1960	17,075	3,072	20,147
1961	18,103	3,240	21,343
1962	14,840	4,278	19,118
1963	12,491	4,025	16,516
1964	17,373	3,529	20,902
1965	13,008	3,520	16,528
1966	11,176	3,155	14,331
1967	17,012	3,899	20,911
1968	28,494	6,046	34,540
1969	37,375	8,105	45,480
1970	39,357	7,950	47,307
1971	29,954	6,786	35,740
1972	20,684	4,370	25,054
1973	27,875	7,448	35,322
1974	36,497	10,430	46,928
1975	44,256	13,856	58,112
1976	44,717	12,622	57,339
1977	55,240	20,515	75,755
1978	52,322	25,002	77,324
1979	61,380	31,935	93,314
1980	95,835	67,261	163,096
1981	112,967	117,664	230,631
1982	79,110	130,482	209,592
1983	64,195	146,202	210,398
1984	65,200	206,336	271,535
1985	58,207	268,482	326,689

TABLE 45

EXPLORATION EXPENDITURES IN CANADA ($ 1987 thousand)

Year	Total Metallic Minerals	Base Metals	Gold	Base Metals and Gold
1946	70,987	10,001	48,920	58,921
1947	51,704	5,384	29,019	34,404
1948	35,740	9,159	15,372	24,531
1949	42,793	10,477	18,932	29,409
1950	44,267	12,819	15,890	28,709
1951	60,714	12,173	12,482	24,655
1952	89,698	19,957	12,761	32,718
1953	109,726	33,381	12,796	46,177
1954	157,977	51,176	16,655	67,831
1955	168,923	61,945	7,103	69,048
1956	270,012	111,096	19,990	131,086
1957	300,236	100,664	15,471	116,134
1958	206,774	61,013	10,166	71,180
1959	253,172	114,580	16,168	130,748
1960	211,963	111,161	16,737	127,848
1961	204,941	113,290	15,963	129,253
1962	203,505	101,653	21,476	123,129
1963	187,320	96,483	19,844	116,327
1964	209,334	129,992	17,588	147,580
1965	228,291	121,119	18,254	139,373
1966	275,191	165,838	18,829	184,667
1967	275,210	168,897	20,025	188,922
1968	365,658	228,568	28,420	256,988
1969	459,576	288,684	36,366	325,050
1970	490,015	314,215	35,624	349,838
1971	393,503	237,944	29,086	267,029
1972	306,426	197,712	20,036	217,749
1973	320,811	204,867	30,761	235,628
1974	307,595	184,892	33,012	217,904
1975	324,294	173,825	42,515	216,340
1976	334,976	165,176	36,425	201,600
1977	411,985	180,676	49,700	230,376
1978	454,605	151,089	64,326	215,415
1979	517,677	188,700	78,565	267,265
1980	690,898	281,975	151,616	433,591
1981	712,525	299,139	230,085	529,224
1982	499,699	168,167	221,835	390,002
1983	430,731	132,800	226,574	359,374
1984	512,451	145,511	302,002	447,513
1985	531,572	99,182	378,876	478,059
1946-55	832,528	226,472	189,930	416,403
1956-65	2,275,553	1,061,050	171,658	1,232,707
1966-75	3,518,279	2,165,440	294,676	2,460,116
1976-85	5,047,121	1,812,415	1,740,004	3,552,419
1946-85	11,723,481	5,265,377	2,396,268	7,661,645

TABLE 46

EXPLORATION EXPENDITURES IN ONTARIO ($ 1987 thousand)

Year	Total Metallic Minerals	Base Metals	Gold	Base Metals and Gold
1946	23,638	786	15,514	16,300
1947	12,077	440	8,608	9,048
1948	7,051	751	4,444	5,195
1949	8,358	882	5,106	5,988
1950	10,288	913	5,114	6,027
1951	21,641	1,325	5,098	6,424
1952	23,464	724	4,605	5,329
1953	37,486	2,001	4,133	6,134
1954	55,786	9,664	6,035	15,699
1955	74,050	14,005	3,841	17,846
1956	86,666	21,123	5,690	28,613
1957	97,176	18,073	6,795	24,868
1958	48,120	7,591	3,846	11,437
1959	38,387	14,650	5,332	19,981
1960	48,549	17,246	4,014	21,261
1961	39,578	13,893	5,073	18,966
1962	40,457	9,013	7,741	16,754
1963	35,743	9,835	4,478	14,313
1964	54,668	12,881	6,560	30,442
1965	56,808	14,174	6,817	20,991
1966	50,756	5,004	6,091	11,094
1967	62,733	18,544	7,527	26,071
1968	85,977	24,852	10,319	35,170
1969	103,810	38,059	12,456	50,515
1970	132,174	60,307	15,861	76,168
1971	89,562	25,413	10,747	36,161
1972	59,862	17,224	7,183	24,407
1973	65,918	23,067	9,889	32,956
1974	60,614	17,703	9,093	26,795
1975	65,227	27,219	10,564	37,783
1976	65,776	27,196	13,759	40,955
1977	72,118	31,634	16,745	48,379
1978	48,552	18,527	17,215	35,742
1979	53,346	24,083	16,960	41,043
1980	99,947	50,348	35,798	86,146
1981	124,374	61,078	50,739	111,817
1982	103,377	29,093	68,865	97,958
1983	112,474	21,488	86,745	108,233
1984	123,122	27,809	89,546	117,355
1985	109,718	13,504	92,318	105,822
1946-55	273,838	31,491	62,498	93,989
1956-65	546,172	149,479	56,345	205,824
1966-75	776,634	257,392	99,728	357,120
1976-85	912,803	304,761	488,689	743,450
1946-85	2,509,447	743,124	707,260	1,450,383

TABLE 47

EXPLORATION EXPENDITURES IN THE SHIELD REGION
($ 1987 thousand)

Year	Base Metals	Gold	Base Metals and Gold
1946	7,607	42,687	50,294
1947	3,526	23,662	27,188
1948	5,439	12,969	18,408
1949	4,913	15,427	20,340
1950	4,025	12,600	16,626
1951	5,879	10,535	16,413
1952	9,185	9,749	18,934
1953	8,997	9,685	18,682
1954	17,815	14,556	32,371
1955	30,727	5,690	36,417
1956	63,629	15,172	78,802
1957	64,656	12,348	77,004
1958	36,369	7,733	44,102
1959	83,585	13,677	97,263
1960	74,912	13,476	88,388
1961	78,889	14,119	93,008
1962	63,818	18,397	82,215
1963	52,671	16,972	69,643
1964	71,412	14,505	85,417
1965	51,673	13,985	65,658
1966	42,331	11,950	54,281
1967	61,917	14,192	76,109
1968	100,075	21,235	121,310
1969	125,515	28,218	152,733
1970	126,311	25,513	151,824
1971	90,041	21,103	111,144
1972	60,838	12,854	73,692
1973	75,354	20,134	95,487
1974	86,309	24,665	110,974
1975	95,159	29,792	124,950
1976	88,550	24,995	113,545
1977	102,973	38,242	141,215
1978	91,880	43,905	135,785
1979	98,012	50,994	149,006
1980	138,441	97,163	235,604
1981	147,196	153,316	300,512
1982	94,830	156,410	251,240
1983	73,310	166,960	240,270
1984	71,996	227,844	299,840
1985	62,320	287,454	349,775
1946-55	98,112	157,561	255,673
1956-65	641,615	104,385	781,999
1966-75	863,849	208,656	1,072,504
1976-85	969,508	1,247,283	2,216,791
1946-85	2,573,082	1,753,884	4,326,967

APPENDIX III

POSSIBLE ECONOMIC DISCOVERIES FOR EVALUATION

Base Metal Deposits: Ontario

	Discovery Date				
Name	Pre-1946	1946-55	1956-65	1966-75	1976-85
BERENS RIVER	x				
BIG NAMA CREEK			x		
BI-ORE	x				
BRISMIL			x		
BRUCE	x				
CHANCE					x
COLDSTREAM		x			
COPPER CORP		x			
COPPER LODE A			x		
COPPER LODE E			x		
CROWNBRIDGE			x		
DIXIE					x
ERRINGTON	x				
F GROUP				x	
GECO		x			
GENEVA LAKE	x				
GOULAIS RIVER				x	
GRASSY PORTAGE			x		
HEADVUE		x			
JAMELAND				x	
JAMIESON			x		
KAM KOTIA	x				
KENDON		x			
KIDD CREEK			x		
KINGDON	x				
KRISTINA	x				
LYON LAKE					x
MATTABI				x	
MAYBRUN		x			
MUNRO COPPER		x			
ONAMAN LAKE				x	
PATER		x			
RYAN LAKE			x		
SCHUMACHER COPPER			x		
SHUNSBY		x			
SOUTH BAY				x	
STRALAK	x				
STURGEON				x	
TEMAGAMI		x			
TRIBAG			x		
UPPER BEAVER	x				
VERMILLION	x				
WILLECHO		x			
WILLROY		x			
WINSTON LAKE					x
ZENMAC	x				

Base Metal Deposits: Other Shield Region

	Discovery Date				
Name	Pre-1946	1946-55	1956-65	1966-75	1976-85
Quebec					
ABCOURT		x			
ALDERMAC	x				
AMOS	x				
AMULET A	x				
AMULET C	x				
AMULET F	x				
ANGLO AMERICAN			x		
ANSIL					x
BARVALLEE			x		
BARVUE		x			
BATEMAN BAY			x		
BELFORT		x			
BELL ALLARD			x		
CAMPBELL MAIN	x				
CEDAR BAY	x				
CONIAGAS		x			
COOKE				x	
COPPER CLIFF		x			
COPPER RAND		x			
COPPER RAND 3		x			
CORBET			x		
CORNER BAY					x
DELBRIDGE			x		
DEVLIN					x
DUNRAINE	x				
EAST SULLIVAN	x				
EAST WAITE		x			
ESTRADES					x
FIGUREY				x	
GARON LAKE			x		
GOLDEN MANITOU	x				
GRANDROY		x			
GRASSET LAKE				x	
GREVET					x
HENDERSON			x		
HORNE	x				
ICON			x		
ISLE DIEU					x
JACULET		x			
JOLIET	x				
JOUTEL			x		
KELLY DESMOND			x		
KOKKO CREEK		x			
LACORNE	x				
LEMOINE				x	

Base Metal Deposits: Other Shield Region (continued)

Name	Discovery Date				
	Pre-1946	1946-55	1956-65	1966-75	1976-85
Quebec (continued)					
LESSARD				x	
LOUVEM				x	
LOUVEM ZINC				x	
MAGUSI				x	
MATTAGAMI			x		
MERRILL ISLAND	x				
MILLENBACH				x	
MOBRUN		x			
NEW CALUMET	x				
NEW HOSCO			x		
NEW INSCO				x	
NORBEC			x		
NORITA			x		
NORITA EAST					x
NORMETAL	x				
OLD WAITE	x				
ORCHAN			x		
PERRY		x			
POIRIER			x		
PORTAGE			x		
PREISSAC	x				
QUEBEC MANITOU			x		
QUEMONT	x				
RIBAGO DEEP					x
ROBATAILLE			x		
SCOTT					x
SELBAIE A1				x	
SELBAIE A2				x	
SELBAIE B				x	
SPRINGER	x				
TACHE LAKE		x			
VAUEE			x		
VENDOME		x			
WAITE DUFAULT	x				
WEST MACDONALD	x				
Manitoba					
ANDERSON LAKE			x		
BOB	x				
CENTENNIAL				x	
CHISEL LAKE			x		
COPPERMAN	x				
CUPRUS	x				
DICKSTONE	x				
FAREWELL LAKE				x	
FLIN FLON	x				

Base Metal Deposits: Other Shield Region (continued)

	Discovery Date				
Name	Pre-1946	1946-55	1956-65	1966-75	1976-85
Manitoba (continued)					
FL-DH		x			
FOX			x		
FRANCES LAKE					x
GHOST LAKE			x		
HYERS ISLAND	x				
JUNGLE			x		
LOST LAKE				x	
MACBRIDE LAKE				x	
MORGAN LAKE					x
NORTH STAR		x			
OSBORNE LAKE		x			
PINEBAY			x		
RAIL LAKE				x	
REED LAKE				x	
ROD				x	
RUTTAN				x	
SCHIST LAKE		x			
SHERRIDAN	x				
SPRUCE POINT				x	
STALL			x		
SYLVIA					x
TROUT LAKE MANITOBA					x
VAMP LAKE	x				
WESTARM				x	
WHITE LAKE			x		
WIM				x	
Saskatchewan					
BIGSTONE LAKE					x
BIRCH LAKE		x			
CALLINAN					x
CORONATION		x			
FLEXAR		x			
GEORGE LAKE				x	
MCKENZIE			x		
RAMSEY				x	
WADEN BAY		x			
Northwest Territories					
AGRICOLA				x	
DEB					x
DIANNE				x	
GONDOR					x

Base Metal Deposits: Other Shield Region (continued)

Name	Discovery Date				
	Pre-1946	1946-55	1956-65	1966-75	1976-85
Northwest Territories (continued)					
HACKETT A				x	
HACKETT BOOT				x	
HACKETT CLEAVER				x	
HEK					x
HENINGA				x	
HIGH LAKE			x		
HOOD 10				x	
HOOD 41				x	
HOOD 41A					x
HOOD 462					x
INDIAN MOUNTAIN		x			
IZOK				x	
JUNE				x	
MUSK					x
NANISIVIK			x		
TURNBACK	x				
WRECK				x	

Base Metal Deposits: Other Canada

	Discovery Date				
Name	Pre-1946	1946-55	1956-65	1966-75	1976-85
Newfoundland					
BETTS COVE	x				
BOUNDARY					x
CLEMENTINE			x		
COLCHESTER	x				
DANIELS HARBOUR			x		
DUCK POND					x
GREAT BURNT LAKE				x	
GULLBRIDGE	x				
LITTLE BAY	x				
LUCKY STKIKE					
MACLEAN		x			
MACLEAN EXTENSION					x
MING				x	
OLD BUCHANS	x				
ORIENTAL NO. 1	x				
ORIENTAL NO. 2		x			
PILLEYS ISLAND	x				
POINT LEAMINGTON				x	
RAMBLER EAST			x		
RAMBLER MAIN	x				
ROTHERMERE		x			
SKIDDER				x	
TILT COVE	x				
TULKS EAST					x
TULKS HILL			x		
WHALESBACK			x		
YORK HARBOUR	x				
Nova Scotia					
GAYS RIVER				x	
JUBILEE				x	
SALMON RIVER			x		
STIRLING	x				
WALTON			x		
New Brunswick					
BRUNSWICK 6		x			
BRUNSWICK 12		x			
CAPTAIN			x		
CARIBOU		x			
CLEARWATER			x		
FLAT LANDING BROOK				x	
HALFMILE LAKE		x			
KEY ANACON		x			

Base Metal Deposits: Other Canada (continued)

Name	Discovery Date				
	Pre-1946	1946-55	1956-65	1966-75	1976-85
New Brunswick (continued)					
LITTLE RIVER		x			
MURRAY BROOK BASE METAL		x			
NIGADOO		x			
PABINEAU RIVER				x	
STRATMAT			x		
THIRD PORTAGE LAKE			x		
WEDGE			x		
Other Quebec					
CAPELTON	x				
CLINTON COPPER			x		
CUPRA			x		
EUSTIS	x				
GASPE Cu MOUNTAIN	x				
GASPE E					x
HARVEY HILL	x				
HUNTINGTON		x			
LINGWICK				x	
MADELAINE				x	
NEEDLE MOUNTAIN	x				
SOLBEC		x			
SUFFIELD	x				
WEEDON	x				
British Columbia					
ADANAC				x	
AFTON				x	
ANNEX				x	
ASHBY	x				
BELL			x		
BENSON				x	
BERG			x		
BETHLEHEM		x			
BIG BONANZA				x	
BIG BULL AND TULSEQUAH CHIEF	x				
BLUEBELL		x			
BONANZA	x				
BOSS MOUNTAIN			x		
BRENDA				x	
BRITANNIA	x				
BLUE GROUSE		x			

Base Metal Deposits: Other Canada (continued)

	Discovery Date				
Name	Pre-1946	1946-55	1956-65	1966-75	1976-85
British Columbia (continued)					
CARIBOO BELL			x		
CATFACE			x		
CHUCHUA CREEK					x
CIRQUE					x
COPPER MOUNTAIN	x				
CRAIGMONT			x		
DANKOE	x				
DAVIS KEAYS				x	
EAGLEHEAD			x		
ENDAKO			x		
GALORE CREEK			x		
GIBRALTER				x	
GLACIER GULCH			x		
GOLDSTREAM				x	
GRANDUC		x			
GRANISLE			x		
HARPER CREEK				x	
HB		x			
HIDDEN CREEK	x				
HIGHMONT			x		
HUCKLEBERRY			x		
HW					x
INDIAN CHIEF	x				
INGERBELLE				x	
ISLAND COPPER				x	
J & L	x				
JA				x	
JERSEY		x			
KING FISSURE			x		
KITSAULT			x		
KUTCHO CREEK				x	
LARA					x
LORNEX			x		
LUCKY JIM	x				
LYNX			x		
MAGGIE				x	
MAGNUM			x		
MIDWAY					x
MINERAL KING		x			
MONARCH	x				
MORRISON			x		
MOTHER LODE AND SUNSET		x			
MYRA FALLS				x	
OK				x	

Base Metal Deposits: Other Canada (continued)

Name	Discovery Date				
	Pre-1946	1946-55	1956-65	1966-75	1976-85
British Columbia (continued)					
ORO DENORO	x				
OWEN LAKE	x				
PHOENIX	x				
PRICE					x
PROSPERITY	x				
RED CHRIS				x	
RED MOUNTAIN			x		
REEVES	x				
ROBB LAKE				x	
RUTH VERMONT	x				
SAM GOOSLY				x	
SAMATOSUM					x
SCHAFT CREEK				x	
SCOTIA			x		
SENECA			x		
SILVER GIANT	x				
SILVER STANDARD	x				
SINMAX CREEK	x				
SNOWSHOE	x				
SOUTH CIRQUE					x
SPOKANE				x	
SULLIVAN	x				
SUNRO			x		
SUNSHINE				x	
SUSTUT				x	
TASU	x				
TROJAN	x				
TROUT LAKE BC				x	
TWIN J	x				
VALLEY COPPER				x	
WINDY GRAGGY			x		
YALE MINE	x				
Other Northwest Territories					
BEAR TWIT				x	
CONWEST 408				x	
CORONET			x		
ECLIPSE			x		
GAYNA				x	
GREAT SLAVE REEF 1					x
GREAT SLAVE REEF 2					x
HOWARDS PASS				x	
JAY				x	
PINE POINT 1	x				

Base Metal Deposits: Other Canada (continued)

	Discovery Date				
Name	Pre-1946	1946-55	1956-65	1966-75	1976-85
Other Northwest Territories (continued)					
PINE POINT 2			x		
PINE POINT 3				x	
PINE POINT 4					x
PINE POINT 5					x
POLARIS				x	
PRAIRIE CREEK				x	
PYRAMID			x		
REDSTONE			x		
Yukon Territory					
ANNIV				x	
ARCTIC CHIEF	x				
BARB			x		
BELLEKENO DEEP					x
BEST CHANCE			x		
BIRMINGHAM	x				
CASH				x	
CASINO				x	
COWLEY PARK			x		
DY					x
ELSA	x				
FARO			x		
GALKENO	x				
GEM				x	
GOZ				x	
GRUM				x	
HART				x	
HECTOR-CALUMET	x				
HUNDERE			x		
HUSKY				x	
HUSKY SOUTHWEST					x
JASON					x
KEEWENAW		x			
KENO	x				
LITTLE CHIEF			x		
LOGAN				x	
LUCKY QUEEN	x				
MEL				x	
MINTO				x	
NADALEEN					x
NO CASH	x				
QUARTZ LAKE		x			
SADIE LADUE	x				
SILVER KING	x				

Base Metal Deposits: Other Canada (continued)

Name	Discovery Date				
	Pre-1946	1946-55	1956-65	1966-75	1976-85
Yukon Territory (continued)					
SWIM			x		
TINTA HILL	x				
TINTINA				x	
TOM		x			
VANGORDA		x			
VENUS	x				
VERA					x
WAR EAGLE	x				
WILLIAMS CREEK				x	

Gold Deposits: Ontario

	Discovery Date			
Name	1946-55	1956-65	1966-75	1976-85
ANNCO		x		
AQUARIUS				x
BELL CREEK				x
BROULAN REEF	x			
CAMERON LAKE				x
CARSHAW				x
CLAVOS				x
DETOUR LAKE			x	
DONA LAKE				x
FAVOURABLE LAKE		x		
GOLDEN PATRICIA				x
GOLDEN ROSE				x
HEMLO				x
H.G. YOUNG	x			
HIGHLAND CROW				x
HOYLE POND				x
HUGH PAM	x			
KREMZAR				x
MAGINO				x
MAGNACON				x
MATHESON EAST				x
MCBEAN				x
MCDERMOTT				x
MISSANABIE	x			
NIGHTHAWK LAKE				x
OPAPAMISKAN				x
OROFINO				x
OWL CREEK			x	
ROBIN RED LAKE		x		
ROMFIELD				x
SCADDING				x
SHOAL LAKE			x	
ST. ANDREWS		x		
SURLUGA		x		
TISDALE				x
WILMAR		x		

Gold Deposits: Other Shield Region

Discovery Date				
Name	1946-55	1956-65	1966-75	1976-85
Quebec				
ASTORIA				x
AUGMITTO				x
BACHELOR LAKE	x			
BEACON				x
BOUSQUET				x
BOUZAN	x			
CALLAHAN				x
CAMFLO		x		
CHADBOURNE				x
CHIBEX (MESTON)	x			
CHIMO		x		
CONS. CENTRAL CADILLAC			x	
DEKA				x
D'ESTOR			x	
DOYON			x	
DUMAGAMI		x		
DUMONT			x	
EAGLE-TELBEL		x		
EASTMAIN				x
ELDRICH	x			
ELLISON				x
FERDERBER				x
GOLDEN POND				x
GOLDEX		x		
GWILLAM			x	
HEVA				x
KIENA		x		
KIERANS				x
LAC SHORTT		x		
MALARTIC HYGRADE		x		
MARBAN		x		
MONTAUBAN				x
MONTAUBAN SOUTH				x
NEW PASCALIS				x
NORBEAU				x
NORLARTIC				x
NORTH PASCALIS				x
ORENADA 4				x
OTISH MOUNTAIN				x
REMNOR WEST				x
SILIDOR				x
SLEEPING GIANT				x
S-3				x

Gold Deposits: Other Shield Region (continued)

Name	Discovery Date			
	1946-55	1956-65	1966-75	1976-85
Manitoba				
BULLMOOSE (TERRA)				x
FARLEY LAKE				x
MACLELLAN (AGASSIZ)		x		
PUFFY LAKE				x
SHERRGOLD				x
SQUALL LAKE	x			
TARTAN LAKE				x
Saskatchewan				
KOMIS (WADDY)				x
MAHOGANY (JOLU)				x
RIO (FLIN FLON)			x	
SEABEE	x			
STAR LAKE				x
TOWER LAKE EAST				x
WEDGE LAKE				x
WEEDY LAKE				x
Northwest Territories				
COLOMAC				x
CORONATION GULF		x		
COURAGEOUS LAKE				x
CULLATON LAKE		x		
INDIN LAKE				x
LOLOR		x		
LUPIN		x		
REN				x
SALMITA			x	
SUPERCREST	x			
TUNDRA	x			

Gold Deposits: Other Canada

Name	Discovery Date			
	1946-55	1956-65	1966-75	1976-85
Newfoundland				
CAPE RAY				x
HOPE BROOK				x
Nova Scotia				
BEAVER DAM				x
COCHRANE HILL			x	
FOREST HILL				x
New Brunswick				
CAPE SPENCER				x
MURRAY BROOK GOLD				x
British Columbia				
AYLWIN				x
BAKER			x	
BIG MISSOURI				x
BALCKDOME				x
CARIBOU				x
CAROLIN			x	
CINOLA			x	
ERICKSON				x
GOLDEN BEAR				x
LAWYERS				x
MASCOT (NICKEL PLATE)				x
REG				x
RICHFIELD				x
SILBAK				x
SULPHERETS				x
TILLICUM				x
TOODOGGONE (ENERGEX)				x
Yukon Territory				
BROWN MCDADE	x			
KETZA				x
MOUNT NANSEN		x		
MOUNT SKUKUM				x

APPENDIX IV

OTHER DISCOVERIES CONSIDERED BUT EXCLUDED FROM THE EVALUATION

Base Metal Deposits: Ontario

Name	Discovery Date	Reason for Exclusion
ABBICAN	1956	Too Small
ALEXANDER	1975	Too Small
AMORADA DEPOSIT	1958	Too Small
BAR-FIN	1906	Too Small
BIG NAMA	1959	Too Small
BILTON OPTION	1956	Too Small
BOYEA LAKE	1952	Too Small
BRIAR COURT	1918	Too Low Quality
BURROWS LAKE	1918	Too Small
CAMPBELL DUKES	Pre-1949	Too Small
CHENEY MINE	1916	Too Small
CHISOLM	1904	Too Small
CLYDE FORKS	1950	Too Small
COPPER PRINCE	1929	Too Small
DANE	1911	Too Small
DELHI PACIFIC	1907	Too Small
DESTORADA	1951	Too Small
DIADEM	1952	Too Low Quality
DUKES, A.V.	1938	Too Small
ELDORADO	1900	Too Small
ELLA LAKE	1952	Too Small
ENTERPRISE	1870	Too Small
ETHEL COPPER	1952	Too Small
EVANS	1907	Too Small
FRONTENAC LEAD	1866	Insufficient Information
GOUDREAU	1921	Too Small
GRAND PORTAGE	Pre-1900	Insufficient Information
HALLAM	1967	Too Small
HANNAM CLAIMS	1953	Too Low Quality
HIGHLAKE-EVENLODE	1937	Too Low Quality
HERMINA	1910	Too Low Quality
HOLLANDIA	1903	Too Small
HORSCROFT	1852	Too Small
HUNT, CORNELIUS	1915	Too Small
HUNT MINE	Pre-1912	Too Small
INTERPROVINCIAL	1928	Too Small
JARDUN	1951	Too Small
JEFFERSON (STACKPOOL)	1908	Too Small
JURY	1906	Too Small
LONG LAKE MINE	1970	Too Small
MAMAINSE	1882	Too Small
MARICONA	1955	Too Low Quality
MASSEY	1905	Too Small

Base Metal Deposits: Ontario (continued)

Name	Discovery Date	Reason for Exclusion
MATARROW	1948	Too Small
MIRONSKY	1963	Too Low Quality
MORDEY	1964	Too Small
OGEMA	1890	Too Small
PATTERSON	1927	Too Small
PENN COBALT	1905	Too Small
PIDGEON MOLY	1946	Too Low Quality
PLAYTER	1942	Too Small
POTTERDOAL	1926	Too Small
PRACE	1973	Too Small
PURDEX (A-D)	1952	Too Small
QUEBEC	1846	Too Small
REGENTRY METALS	1940	Too Small
RENPRIOR (RENFREW ZN)	1922	Too Small
RICHARDS	1952	Too Small
ROCK LAKE	1898	Too Small
ROSS, C.G.	1914	Too Small
SABINE	1981	Insufficient Information
SATELLITE	1916	Too Small
SETTING NET LAKE	1969	Too Low Quality
SHEBA	1960s	Too Small
SIMON	1961	Too Low Quality
SPAIN	1912	Too Small
STEINBERG	1919	Too Small
SUNSET	1916	Too Small
THUNDER BAY	1927	Too Small
TREHWAY-OSSIAN	1929	Too Small
TROUT BAY	1958	Too Small
TWIN LAKES	1956	Too Small
VANGUARD	1949	Too Small
WILCOX	1893	Too Small
ZINC LAKE	1912	Too Small

Base Metal Deposits: Other Shield Region

Name	Discovery Date	Reason for Exclusion
Quebec		
ABITIBI COPPER	1952	Too Low Quality
ALLARD RIVER	1946	Too Low Quality
BEAUCHASTEL (DESPINA)	1926	Too Small
BEAUDRY	Pre-1938	Too Small
BELL CHANNEL	1961	Too Small
BROMPTON	1965	Too Low Quality
BRUNEAU MINE	1962	Too Small
CANRAY	1976	Too Low Quality
CERTAC (LAC CERE)	1953	Too Low Quality
CHIB COPPER	1957	Too Small
CRYSLER NO. 2	1952	Too Low Quality
DIK DIK	1951	Too Small
DON ROUYN	1925	Too Low Grade
DUMONT BOURLAMAQUE	1969	Too Small
DUVAN	1954	Too Small
D-68	1952	Too Small
EMPIRE LE TAC	1952	Too Low Quality
FRANELLE	1976	Insufficient Information
FREDERICKSON LAKE	1942	Insufficient Information
HALIWELL	1929	Too Small
HEIGHT OF LAND	1906	Too Small
HEMATITE BAY	1908	Too Low Quality
HUNTER MINE	1955	Too Small
JIMMICK LAKE	1960	Too Small
JOSEPH CLAIMS	1968	Too Small
JOSSELIN	1968	Too Small
KIRKHAM	1952	Too Low Quality
KOKE	1961	Too Low Grade
LAC MOLEAN	1962	Too Small
LAFONTAINE	1945	Too Small
LEITCH	1967	Too Small
LETAC	1952	Insufficient Information
LYNDHURST	1951	Too Small
MILLER COPPER	1956	Too Low Quality
MILLSTREAM	1968	Too Small
MOLY HILL	1939	Too Low Quality
MONPAS	1956	Too Small
MOSS MINE	1916	Too Small
NEPTON BAY	1951	Too Low Quality
NEW BIDLAMAQUE	1938	Insufficient Information
ORENADA	1923	Too Low Quality
PERCH RIVER	1967	Too Small
PRUDHOMME 1	1964	Too Low Quality
QUEBEC CHIBOUGAMAU GOLDFIELDS	1951	Too Low Quality

Base Metal Deposits: Other Shield Region (continued)

Name	Discovery Date	Reason for Exclusion
Quebec (continued)		
RIBOURDE-SASSURE	1970	Insufficient Information
RICHMOND GULF	1948	Too Low Quality
RIO ALGOM CHIBOUGAMAU	1976	Insufficient Information
SOUCY	1954	Too Low Quality
SOUTH DUFAULT	1947	Too Low Quality
SOUTH RUSTY HILL	1956	Too Low Quality
TRINITY	1947	Too Small
VALRAY (CRANGOLD)	1931	Too Small
WRIGHT MINE	1875	Too Small
Manitoba		
BARRINGTON LAKE	1970	Too Small
GOODENOUGH	1952	Too Small
MANDY	*	Too Small
NORRIS LARE	1980	Too Low Quality
POT LAKE	1956	Too Small
WEST FRANCES	1976	Too Low Quality
Z DEPOSIT	1947	Too Small
Saskatchewan		
ELIZABETH LAKE	1970	Too Low Quality
MOKOMAN (KNIFE LAKE)	1971	Too Low Quallty
PITCHING LAKE	1956	Too Small
SCHOTTS LAKE	1953	Too Low Quality
HANSEN LAKE	1957	Too Low Quality
Northwest Territories		
CARL 7	1968	Too Small
CORONATION	1969	Too Small
CW GROUP	1957	Too Small
DICK NO 1	1952	Too Small
HOMER	1945	Insufficient Information
MARINER	1968	Too Small
NOREX MINE	1967	Too Small
O'CONNER LAKE	1948	Too Small

* discovery date unknown

Base Metal Deposits: Other Canada

Name	Discovery Date	Reason for Exclusion
Newfoundland		
BIG RAMBLER POND	1969	Too Small
BUCHANS WEST	*	Too Small
HAND CAMP	1928	Too Small
LA MANCHE	1855	Too Small
LADY POND	Pre-1900	Too Small
LAKE BOND	1952	Too Small
LOCKPORT	1870	Too Small
MCNEILY	Pre-1906	Too Small
MILES COVE	1898	Too Small
MUD POND	1937	Too Small
ROUND POND	1968	Too Small
SOUTH POND	1950	Too Small
TERRA NOVA	1862	Too Small
Nova Scotia		
COXHEATH	Pre-1900	Too Small
DEEP COVE	1964	Too Low Quality
LIME HILL	1968	Too Small
LOCHABER LAKE	1970	Too Low Quality
MEAT COVE	1953	Too Low Quality
SMITHFIELD	Pre-1900	Too Low Quality
New Brunswick		
PORTAGE LAKE	*	Too Small
ANNIDALE	1900	Too Small
ARMSTRONG A&B	1956	Insufficient Information
BENJAMIN RIVER	1895	Too Low Grade
BERESFORD	1952	Too Small
DORCHESTER	1870	Too Low Grade
DRUMMOND IRON	1952	Insufficient Information
EVANDALE	1967	Insufficient Information
KEYMET MINE	1946	Too Small
LEGACY	1970	Too Low Quality
MCMASTER	*	Insufficient Information
NEPISIQUIT	1956	Insufficient Information
NICHOLAS DENYS 1	1965	Too Low Quality
NINE MILE BROOK	1975	Too Small
ORVAN BROOK	1945	Too Small
ROCKY TURN	1956	Insufficient Information
TAYLOR BROOK	1977	Too Low Grade
TEAHAN	Pre-1900	Too Small

* discovery date unknown

Base Metal Deposits: Other Canada (continued)

Name	Discovery Date	Reason for Exclusion
Other Quebec		
ARSENAULT LAKE	1973	Insufficient Information
ASCOT	*	Too Low Quality
BASKET RIVER	1968	Too Small
CANDEGO	1946	Too Small
FEDERAL	1916	Too Small
IVES MINE	1865	Too Low Quality
MID-PATAPEDIA	1968	Insufficient Information
MT ST. SEBASTIEN	1956	Too Low Quality
PEKAN BROOK	1965	Too Low Quality
PANET METALS	1953	Too Low Quality
PORTNEUF MINERALS	1954	Insufficient Information
UPTON	1847	Too Low Quality
British Columbia		
ABBOTT	1894	Too Small
AJAX	1965	Too Low Quality
ALKOKELEX	*	Insufficient Information
ALVIJA	1908	Too Small
ANN (GNAWED MTN.)	1969	Too Low Quality
ANNEX	1966	Too Small
AXE	1969	Too Low Quality
BAM (ARCTIC LAKE)	1967	Too Small
BC AND ZINZ CLAIMS	1967	Tos Small
BELL MOLY	1966	Too Low Quality
BEND	1967	Too Low Quality
BEVERLY	1951	Too Low Quality
BIG LEDGE	1947	Too Low Quality
BIG ONION	1972	Too Low Quality
BULL RIVER	1968	Insufficient Information
BUZZER	1966	Too Low Grade
CADILLAC	1956	Insufficient Information
CAFB	1959	Too Low Quality
CANAM	1935	Too Low Quality
CARMI & LAKE	1970	Too Low Quality
CATHERINE	1903	Too Small
CLEARWATER	1987	Too Recent
COLBY	*	Insufficient Information
COLLOSSUS	1966	Too Small
COMMERCE	1970	Too Small
COPPER CANYON	1960	Too Low Quality
COPPER CROWN	Pre-1920	Too Small
COPPER ROAD	1963	Too Small
COTTON BELT	1925	Insufficient Information
CRONIN	1948	Too Small

* discovery date unknown

Base Metal Deposits: Other Canada (continued)

Name	Discovery Date	Reason for Exclusion
British Columbia (continued)		
CROWN POINT	1928	Too Small
CROY	1970	Too Small
DIVIDE COPPER	1957	Too Low Quality
DOLLY VARDEN	1972	Too Small
DOROTHY	1971	Too Low Grade
DOUBLE ED	1935	Too Low Quality
DRIFTPILE	1979	Too Low Quality
DUNCAN	1961	Too Remote
ECSTALL	1901	Too Low Quality
EDEN	1954	Too Small
EMERALD GLACIER	1950	Too Small
EVENING STAR	1900	Too Low Quality
FISH LAKE	1961	Too Low Quality
FRISCO	1912	Too Low Quality
FX (KINGFISHER)	1960	Too Low Quality
GALLOWAY (PAY)	1963	Too Small
GAMBIER ISLAND	1967	Too Low Quality
GATAGA	*	Insufficient Information
GEORGE COPPER	1927	Insufficient Information
GIANT	1965	Too Low Quality
GOLDEN QUEEN	Pre-1900	Too Small
GREYHOUND	Pre-1916	Too Small
GUNN (HD)	1967	Too Low Quality
HASKIN MTN SE	1969	Insufficient Information
HASKIN MTN WEST	1969	Too Low Grade
HAWK CREEK	1942	Too Small
HI HO	1971	Too Low Quality
HOWE COPPER	1966	Too Low Quality
JACK POT	1902	Too Low Quality
JB	1965	Too Low Quality
JERICHO	1959	Too Low Quality
JOE (IRON CAP)	1956	Too Small
JUBILEE MOUNTAIN	*	Insufficient Information
KAREN (TRAPPER)	1972	Too Low Quality
KELLY CREEK	1965	Too Low Quality
KLISUM	1970	Too Low Quality
KOOTENAY KING	1928	Too Small
KRAIN	1955	Too Low Quality
KWANKIA	1967	Too Low Grade
LEEMAC	1971	Too Low Quality
LILY	1900	Too Small
LORNA	1900	Too Low Quality
LORRAINE	1970	Too Low Quality
LUCKY FOUR	1918	Too Small
LUCKY SHIP	1965	Too Low Quality

* discovery date unknown

Base Metal Deposits: Other Canada (continued)

Name	Discovery Date	Reason for Exclusion
British Columbia (continued)		
LUSTDUST	1954	Too Small
MAMIE	1963	Too Small
MAPLE BAY	1923	Too Small
MASTADON ZINC	1949	Too Small
MCDAME-BELL	1964	Too Small
MCVICAR	1925	Too Small
MER	1965	Too Low Quality
MINEX	1968	Too Low Quality
MISTY	1973	Too Low Quality
MOLLY GIBSON	1906	Too Small
MOSQUITO KING	1965	Too Small
MT OGDEN	1967	Too Low Grade
NANIKA (DW)	1968	Too Low Quality
NORTHWEST	1973	Too Small
OWL (COPPER QUEEN)	1928	Too Low Quality
OX LAKE	1968	Too Low Quality
PARADISE	1900	Too Small
PARAMOUNT MINING	1970	Too Low Quality
PAYNE	1891	Too Small
PEN (YUBET)	1965	Too Small
POISON MOUNTAIN	1966	Too Low Quality
POMEROY	Pre-1920	Too Small
POPLAR	1975	Too Low Quality
PORCUPINE	1964	Too Small
PRIMER	1966	Too Low Quality
PYTHON	1900	Too Low Quality
RAINBOW	1896	Too Low Quality
RED WING	1966	Too Small
REGAL AG (SNOWFLAKE)	1930	Too Small
REY	1973	Too Low Quality
RIVER JORDAN	*	Insufficient Information
ROCKLAND	1899	Too Low Quality
RONDAH	1972	Too Low Quality
ROUNDY CREEK	1968	Too Low Quality
RUDDOCK CREEK	1962	Too Low Quality
SAWMILL	1979	Insufficient Information
SERB CREEK	1966	Too Low Quality
SILVER BASIN	1969	Too Small
SILVER CHIEF	1915	Too Small
SILVER KING	1965	Too Small
SILVER QUEEN	1955	Too Low Quality
SPAR 1	1949	Too Small
STEAMBOAT	*	Insufficient Information
STEMWINDER	*	Too Small
STORIE	1965	Too Low Quality
ST. EUGENE	*	Insufficient Information
SUMMERS CREEK	1972	Insufficient Information

* discovery date unknown

Base Metal Deposits: Other Canada (continued)

Name	Discovery Date	Reason for Exclusion
British Columbia (continued)		
SUNNY CAVE	1923	Too Small
SUNSHINE CREEK	1966	Too Low Quality
SUSAP (KING EDWARD)	1903	Too Low Quality
TEDDY GLACIER	1963	Too Small
TEDI	1973	Too Small
THOMLINSON MTN	1965	Too Low Quality
TOD RIVER	1967	Too Low Quality
TORIC	1924	Too Small
TORO	1966	Too Small
TROJAN	1957	Too Low Quality
TRUE FISSURE	1900	Too Small
USEBELL	1960	Too Small
VANGUARD	1926	Too Small
VICTOR	1952	Too Small
VIMY 100	1900	Too Low Quality
VULCAN	*	Insufficient Information
WAGNER	1949	Too Small
WARHORSE (BOY SCOUT)	1949	Too Small
WHEAL	1964	Too Low Quality
WHIT	1965	Too Low Quality
WIGWAM	1924	Too Low Quality
WIT, WAG	1964	Too Small
WIZ 21 & 30	1965	Too Low Quality
WOLF	1915	Too Small
YREKA MINE	1954	Too Small
ZIP	1968	Too Small
ZYMOETZ	1966	Insufficient Information
Other Northwest Territories		
PR	1971	Too Small
RAM AND ROD	1973	Insufficient Information
ROY	1981	Too Small
VENUS	1972	Too Small
WRIGLEY	1974	Too Low Quality

* discovery date unknown

Base Metal Deposits: Other Canada (continued)

Name	Discovery Date	Reason for Exclusion
Yukon Territory		
BLACK CUB	1970	Too Small
CLARK	1973	Too Small
CLEAR LAKE (SUE)	1978	Too Low Quality
EAGLE	1970	Too Small
FORMO	1930	Too Small
GROUNDHOG (AG CREEK)	1969	Insufficient Information
HORN	1970	Too Low Quality
KETZAKEY (KEY AND STUMP)	1947	Too Remote
KODIAC CUB	1970	Too Small
LOGJAM CREEK	1977	Too Low Quality
LOOKOUT	1918	Insufficient Information
MARK GROUP	1966	Insufficient Information
PESCO-REX	1962	Too Small
PIKE LAKE	1967	Too Low Quality
SHANGHAI	1966	Too Small
TUF	1960	Too Small
VAL	1978	Too Low Quality
WIND R (AHEARNE)	1970	Too Small

Gold Deposits: Ontario

Name	Discovery Date	Reason for Exclusion
ABINO	1975	Insufficient Information
BEGGS LAKE	1959	Too Small
BOSTON TWP	1980	Too Small
CAMRECO	1980	Insufficient Information
CANREOS	1946	Insufficient Information
EGO	1961	Insufficient Information
GARRISON	Pre-1970	Too Small
KLOTZ LAKE	1983	Insufficient Information
LOUANNA	1946	Too Small
MATTAWASAGA	1984	Insufficient Information
NORSTAR	1958	Too Small
OROSTAR	1974	Too Small
ORPIT	1973	Insufficient Information
RESERVE LAKE	1960	Too Small
SAPAWE	1960	Too Small
SHINING TREE	1984	Insufficient Information
SNOPPY LAKE	1986	1986 Discovery

Gold Deposits: Other Shield Region

Name	Discovery Date	Reason for Exclusion
Quebec		
BROSNAN	1980	Insufficient Information
CANRAY	1976	Insufficient Information
COSEGO	1982	Insufficient Information
COURVAN	Pre-1975	Too Small
DALEMBERT	1982	Insufficient Information
DARIUS	1974	Mined Previously
DESJARDINS TWP	1955	Too Small
DOUAY TWP	Post-1974	Insufficient Information
DOVERCLIFF	1979	Insufficient Information
FABRIEN	1982	Insufficient Information
FLORIDAN	Post-1974	Too Small
GARNEY	1961	Insufficient Information
GOLD SEARCH	1980	Insufficient Information
GOLDSTACK	1981	Insufficient Information
HOSCO	1982	Old Discovery
JOUBI	1973	Too Small
KEN-CHIB	1955	Insufficient Information
LAC MONTIGNY	Post-1974	Insufficient Information
LYNDHURST	1951	Too Small
MALARTIC	1982	Too Low Grade
MALARTIC HYGRADE NEW	1986	1986 Discovery
MALARTIC HYGRADE #8	1985	Too Small
MONIQUE	1983	Insufficient Information
OKENADA	1974	Insufficient Information
PANDORA	1980	Insufficient Information
QUESABE	1947	Too Small
RAND MALARTIC	1985	Too Small
REMINOR	1980	Mined Previously
SOISSAN	1981	Insufficient Information
VAL ST. GILLIS	1979	Too Small
VALIANT	1964	Too Small
VAUGUELIN	1964	Too Small
VINRAY	1946	Too Small
WESTERN QUEBEC	1979	Insufficient Information
WRIGHTBAR	1986	1986 Discovery
Manitoba		
JEEP	1947	Too Small
NOKOMIS LAKE	1960	Too Small
NORRIS LAKE	1946	Too Small
VAMP LAKE	1964	Insufficient Information
WADEK BAY	1952	Base Metals
Northwest Territories		
ARSENO	1946	Too Small
CAMLAREN	1974	Too Small
CASS ZONE	1986	1986 Discovery
RED CLAIM	1985	Too Small
SHEAR LAKE	1983	Too Low Quality
VOL	1962	Too Small

Gold Deposits: Other Canada

Name	Discovery Date	Reason for Exclusion
Nova Scotia		
FIFTEEN MILE STREAM	1985	Too Small
New Brunswick		
ELM TREE	1985	Too Small
British Columbia		
CAPOOSE LAKE	1979	Too Low Grade
CITY OF PARIS (LEXINGTON)	1968	Insufficient Information
COPCO	1959	Too Small
CUSAC	1985	Too Small
DOME MOUNTAIN	1986	1986 Discovery
DUSTY MAC	1968	Too Small
FRASER GOLD	1983	Insufficient Information
FRENCH	1950	Too Small
IMPERIAL	Post-1974	Too Small
KENVILLE	1946	Too Small
LACANA	1985	Insufficient Information
MOSQUITO CREEK	1973	Too Small
NEW PRIVATEER	1983	Too Small
NUTTLUDE	1979	Too Low Grade
SHE-SHAS	1983	Insufficient Information
SMITH NASH	1960	Insufficient Information
TAURUS	1979	Too Small
Yukon Territory		
ARCTIC GOLD	1965	Too Small
VENUS MINE	1966	Too Small

APPENDIX V

GENERAL REVENUE AND COST RELATIONSHIPS

Smelter Return Conditions

General Formula

$$NSV = \left[\frac{(M-D)(P-r)}{100}\right] - \left[T + t(P-P_{ev})\right] + C$$

where:

NSV = net smelter value per tonne of concentrate at the smelter;
M = grade of concentrate, %;
D = unit deduction, %;
p = metal price, \$/tonne;
r = refining charge, \$/tonne of metal;
T = treatment charge, \$/tonne of concentrate;
t = treatment charge price adjustment;
P_{ev} = expected value metal price, \$/tonne;
C = credit for other metals contained, \$/tonne of concentrate.

Notes: penalties are neglected; all concentrate values are expressed on a dry tonne basis.

Copper Concentrate

Unit deduction (D): function of M

M	D
up to 30%	1.0
30%-40%	1.2
over 40%	1.4

t = 0.0
r = 315
T = 115

Credits (C):

Au - pay for 98% above 1 gram per tonne in concentrate
Ag - pay for 98% above 30 grams per tonne in concentrate

$$\text{NSV} = \left[\frac{(M-D)(P-315)}{100}\right] - 115 + C^*$$

$$^* C_{au} = (M_{au}-1)(.98\ P_{au})$$

$$C_{ag} = (M_{ag}-30)(.98\ P_{ag})$$

Lead Concentrate

Unit Deduction (D): the greater of .05(M) or 3

r = 130
T = 165
t = .075

Credits (C):

Au - pay for 96% above 1 gram per tonne in concentrate
Ag - pay for 96% above 45 grams per tonne in concentrate

$$\text{NSV} = \left[\frac{(M-D)(P-130)}{100}\right] - \left[165 + .075(P-P_{ev})\right] + C^*$$

$$^* C_{au} = (M_{au}-1)(.96\ P_{au})$$

$$C_{ag} = (M_{ag}-45)(.96\ P_{ag})$$

Zinc Concentrate

Unit Deduction (D): the greater of .15(M) or 8

$r = 0.0$
$T = 275$
$t = 0.10$

Credits (C):

Ag - pay for 80% above 50 grams per tonne in concentrate
Cd - pay for 65% above .15% in concentrate

$$NSV = \left[\frac{(M-D)(P)}{100}\right] - \left[275 + .010(P-P_{ev})\right] + C^*$$

$$* \; C_{ag} = (M_{ag}-50)(.8\ P_{ag})$$

$$C_{cd} = (M_{cd}-.15)(.65\ P_{cd})/100$$

Concentrate Transportation Costs

Road: 4.3 cents per tonne-km in provinces
8.6 cents per tonne-km in territories
17.2 cents per tonne-km in shield region of Northwest Territories

Rail: up to 500 km, 5.0 cents per tonne-km
500-1500 km, 3.0 cents per tonne-km
over 1500 km, 2.5 cents per tonne-km
14.4 cents per tonne-km in territories

Ocean: Eastern Canada-Europe, $36 per tonne concentrate
Eastern Canada-Japan, $80 per tonne concentrate
Western Canada-Japan, $50 per tonne concentrate
Western Canada-Europe, $58 per tonne concentrate
Within Eastern or Western Canada, $22 per tonne concentrate

Transfer: $5 per tonne concentrate at each transfer point
no. of transfer points = (no. of modes + 1)

Gold Marketing Charges

1. Free Milling Gold Ores
   - assume impure bullion (doré) produced;
   - charge $0.48 per gram ($15 per ounce) of gold content for transportation, refining, and marketing;
   - pay for 98 percent of silver byproduct content.

2. Refractory Gold Ores
   - assume gold concentrate produced;
   - charge $1.29 per gram ($40 per ounce) of gold content for transportation, refining, and marketing;
   - pay for 96 percent of silver byproduct content.

General Deposit Costing Relationships

The generalized deposit costing relationships used in the appraisal when actual data are not available have been developed by T.A. O'Hara. The costing functions provide an order-of-magnitude (±30 percent) level of accuracy. These relationships are outlined as follows:

- mine and mill ore capacity for open pit and underground mines as a function of recoverable ore reserves;
- site preparation cost for open pit mining as a function of topography and tree growth;
- preproduction waste stripping cost as a function of the amounts of soil and waste rock overburden to be removed;
- capital cost of open pit equipment as a function of the annual tonnage of ore and waste to be removed, optimum shovel size, optimum truck size, and drilling conditions;
- capital cost of open pit repair and maintenance facilities as a function of the annual tonnage of ore and waste to be removed;
- capital cost of shaft sinking as a function of rock conditions, mine capacity, and shaft depth;

- capital cost of hoisting plant as a function of mine capacity and hoisting distance;
- capital cost of mine compressor plant as a function of mine capacity;
- underground mine development capital cost as a function of mine capacity and average stope width;
- capital cost of underground mining equipment, maintenance facilities, and sustaining capital requirement as functions of mine capacity and average stope width;
- capital cost of mineral processing plant as a function of ore capacity, topography, tree growth, temperature conditions, hardness of ore, and ore type. Estimated by component: site clearing and mass excavation, concrete foundations and detailed excavation, primary crusher, coarse ore storage, conveying and fine crushing plant concentrator building, fine ore storage and grinding, and the processing section;
- capital cost of electric power supply as a function of mine capacity, mine location and remoteness;
- capital cost of tailings storage as a function of mine capacity, topography, site accessibility, and environmental requirements;
- capital cost of water supply as a function of mine capacity;
- working capital requirement expressed in number of months of operating cost as a function of remoteness;
- number of persons employed as a function of mining method, mine and mill capacities, and employee accommodation provided;
- typical milling recoveries, concentrate grades, and flow of metals among concentrate products, as functions of ore types;
- capital cost of mine access road as a function of topography and distance;
- capital cost of houses, permanent bunkhouse facilities, and townsite amenities as functions of the percentages of employed persons to be accommodated, and remoteness;
- capital cost of general plant services as a function of number of employees;
- project overhead costs as a function of direct project costs;
- operating labour costs for mining, milling, maintenance, and services as a function of mine and mill capacities, mine and mill methods, stope width, and employee accommodation requirements;

- operating materials costs for mining, milling, maintenance, and services as a function of mine and mill capacities, mine and mill methods, stope width, and remoteness;
- electric power operating cost as a function of capacity, location and remoteness.

These order-of-magnitude costing relationships are indexed for variations in construction and mining wage rates among the provinces and territories, and the labour and materials costs can be indexed where appropriate to allow for remoteness cost premiums.

APPENDIX VI

INCOME AND MINING TAXATION SYSTEMS

Taxation Systems in Ontario

Federal Corporate Income Tax

Cash Flow Format:

Revenue
- Operating Cost
- Capital Cost Allowance @ 30% db (optional)
- Interest Payments

If negative: Carried Loss (for year X+1 or X-1)

Revenue
- Operating Cost

Net Income before Allowances
- Capital Cost Allowance

Resource Profits
- Resource Allowance
- Interest Payments
- Exploration Expenditures
- Development Expenditures

Income for Earned Depletion
- Earned Depletion Allowance
- Carried Loss (from X-1 or X+1)

Income for Federal Corporate Income Tax
Federal Corporate Income Tax Otherwise Payable
- Investment Tax Credit

Net Federal Corporate Income Tax Payable

Capital Cost Allowance: applied to mine plant and machinery, the mill facility, infrastructure capital, and mine development capital after the start of commercial production. The amount allowable must be reduced by the investment tax credit (see below).

For capital expended during the development stage and for expansions of at least 25% in capacity, the deduction permitted is the greater of 15% of the allowable capital cost in the year of expenditure and 30% per year thereafter on a declining balance basis, or an amount equal to (revenue - operating cost - interest payments) from the new mine, i.e. at 100% against new mine income.

ASSUME - taxation on an individual project basis will use the 100% rate. Taxation on an integrated company basis will use the 15% and 30% rates until new mine income begins and then the balance will be deducted at the 100% rate. Note that while capital cost allowance reduces the amount of resource profits and resource allowance, a carried loss does not. Therefore, using the 15% and 30% rates until new mine income begins may be advantageous even on the individual project basis.

For other capital costs (apart from major expansion) and sustaining capital costs, the capital cost allowance is 15% of the capital cost in the year of expenditure and 30% per year thereafter on a declining balance basis for all except mine development capital costs which are allowable at 100%.

Capital expenditures incurred to control air and water pollution can be deducted at 50% per year on a straight-line basis.

Resource Allowance: 25% of resource profits.

Development Expenditures: mine development capital costs incurred before the start of commercial production are allowed to be deducted at 100%.

Earned Depletion Allowance: $1 for every $3 of allowable capital costs and expenditures up to a maximum of 25% of income for earned depletion in any year.

Allowable capital costs and expenditures include exploration expenditures; mine development, mine plant and machinery, mill facility, and infrastructure capital in the development stage; mine plant and machinery, and mill facility capital associated with a major expansion; and the processing machinery equipment component in other capital costs (other than major expansions) and sustaining capital costs. The amount allowable must be reduced by the investment tax credit (see below).

Carried Loss: losses may be carried back three years and ahead seven years.

Federal Corporate Income Tax: 33% of income for federal tax, plus 3% surtax. Effective tax rate = 33 + 3 (.33) = 33.99%.

Investment Tax Credit: applies to mine plant and machinery, mill facility and infrastructure capital. The investment tax credit is deducted from the federal corporate income tax which would otherwise be payable to determine the net tax payable. The maximum deduction in any year is the federal corporate income tax otherwise payable.*

The rate of tax credit is 20% for applicable investment in the Atlantic Provinces and the Gaspé region of Quebec.

---

* As a temporary measure for the period May, 1983 - December, 1988, 20% of any investment tax credits earned in excess of the federal tax otherwise payable is returnable as a cash refund.

Ontario Corporate Income Tax

Cash Flow Format:

Revenue
- Operating Cost
- Capital Cost Allowance @ 30% db (optional)
- Interest Payments

if negative: Carried Loss (for year x+1 or x-1)

same format as for Federal Corporate Income Tax

Revenue
- Operating Cost

Net Income before Allowances
- Capital Cost Allowance
- Interest Payments
- Exploration Expenditures
- Development Expenditures

Income for Percentage Depletion
- Percentage Depletion Allowance
- Carried Loss (from year X-1 or X+1)

Income for Ontario Corporate Income Tax
Ontario Corporate Income Tax

Capital Cost Allowance
Development Expenditures
Carried Loss

Same rules as for Federal Corporate Income Tax

Percentage Depletion Allowance: 33 1/3% of income for percentage depletion.

Ontario Corporate Income Tax: 14.5% of income for Ontario income tax.

Ontario Mining Tax

Cash Flow Format:

Revenue
- Operating Cost

Net Income before Allowances
- Depreciation Allowance
- Exploration Expenditures

Income for Processing Allowance
- Processing Allowance

Income for Ontario Mining Tax
Ontario Mining Tax

Depreciation Allowance: mine development capital costs at 100% per year; mine plant and equipment at 30% per year on a straight-line basis; mill, infrastructure and all other capital costs at 15% per year on a straight-line basis.

Processing Allowance: annual rate applied to the original cost of processing assets but not to be less than 15% nor more than 65% of income for processing allowance.

8% if ore concentrated
12% if ore smelted in Canada
16% if ore refined in Canada
20% if ore refined or fabricated in northern Ontario

Rate applies to all processing assets up to and including final stage.

The 12% rate applies to gold mill assets if the facility includes a smelter which produces dore or impure bullion.

Three-Year Tax Exempt Period: a new mine is exempt from Ontario mining tax for a period of three years from the start of production.

Ontario Mining Tax:

income for mining tax	marginal rate
up to 500,000	exempt
500,000 and over	20%

Provincial and Territorial Corporate Income Taxation Elsewhere in Canada

Quebec

Cash Flow Format:

Revenue
- Operating Cost
- Capital Cost Allowance @ 30% db (optional)
- Interest Payments

if negative: Carried Loss (for year X+1 or X-1)

Revenue
- Operating Cost

Net Income before Allowances
- Capital Cost Allowance
- Resource Profits
- Resource Allowance
- Interest Payments
- Exploration Expenditures
- Development Expenditures

same format as for Federal Corporate Income Tax

Income for Earned Depletion
- Earned Depletion Allowance
- Carried Loss (from X-1 or X+1)

Income for Quebec Corporate Income Tax
Quebec Corporate Income Tax

Capital Cost Allowance
Resource Allowance
Development Expenditures
Carried Loss

Same rules as for Federal Corporate Income Tax

Earned Depletion Allowance: same rules as for federal corporate income tax except maximum annual deduction is 33 1/3% of income for earned depletion.

Quebec Corporate Income Tax: 5.5% of Income for Quebec income tax.

Other Provinces and Territories

In British Columbia, resource allowance is not an allowable deduction in calculating income for B.C. corporate income tax. Otherwise, income for provincial and territorial corporate income tax is derived in exactly the same way as income for federal corporate income tax.

The applicable tax rates are as follows:

Alberta	11%
British Columbia	14%
Manitoba	17%
New Brunswick	15%
Newfoundland	16%
Northwest Territories	10%
Nova Scotia	15%
Saskatchewan	17%
Yukon Territory	10%

Provincial and Territorial Mining Taxation Elsewhere in Canada

Newfoundland*

Cash Flow Format:

Revenue
- Operating Cost

Net Income before Allowances
- Depreciation Allowance
- Exploration Expenditures

Income for Processing Allowance
- Processing Allowance

Income for Newfoundland Mining Tax
Newfoundland Mining Tax

Depreciation Allowance: all pre-production capital costs allowable on a straight-line basis over estimated, mine life. Capital expended during the productive life of a mine is allowable at 10 percent on a straight-line basis.

Processing Allowance: 8% per year of the original cost of processing assets but not to be more than 65% of the income for processing allowance.

Newfoundland Mining Tax: 20% on first 20% of income for Newfoundland mining tax; 15% on remaining income for Newfoundland mining tax.

---

* Several mining companies have special royalty agreements with the Newfoundland government which override the general mining taxation policies outlined here. For example, the operations of the Iron Ore Company of Canada are governed by the Labrador Mining and Exploration Act of 1938 as amended. The method by which the province derives revenue from Wabush Mines' iron ore operation is determined by the Nalco-Javelin Mineral Lands Act as amended.
Base metal and gold deposits discovered on the Anglo-Newfoundland Development (AND) charter lands in the Buchans area, presently controlled by the Selco Division of BP Resources, are subject to the provisions of the Manufacture of Pulp and Paper Act of 1905 as amended. A royalty of 5 percent of taxable income is in this case payable. Depreciation allowance is 10 percent of capital costs per year on a straight-line basis. There is no processing allowance.
The application of such special arrangements is not considered in the present study.

Nova Scotia

Cash Flow Format:

Gross Metal Revenue
- Smelting, Refining, and Transportation Charges

Revenue = Net Smelter Return

Revenue
- Operating Cost

Net Income before Allowances
- Depreciation Allowance
- Exploration Expenditures

Income for Processing Allowance
- Processing Allowance

Income for Nova Scotia Mining Tax
Nova Scotia Mining Tax

Depreciation Allowance: all capital costs except post-production mine access capital costs allowable at 100% against new mine income during the first three years of operation and at 30% per year on a straight-line basis thereafter. Post-production mine development capital costs allowable at 100%.

Processing Allowance: 8% per year of the original cost of processing assets but not to be less than 15% nor more than 65% of the income for processing allowance.

Nova Scotia Mining Tax: the greater of 2% of net smelter return or 15% of income for Nova Scotia mining tax (but subject to change by order-in-council).

New Brunswick

Cash Flow Format:

Revenue
- Operating Cost
- Exploration Allowance
- Royalty
- Depreciation Allowance
- Interest Allowance

Income for Processing Allowance
- Processing Allowance

Income for New Brunswick Mining Tax
New Brunswick Mining Tax
- Research Credit

New Brunswick Mining Tax After Credit

Exploration Allowance: $1.50 for every $1 of exploration expenditures.

Royalty: 2% of 'net mill return' starting in the third year of mine operation.

Gross Metal Revenue
- Smelting, Refining, and Transportation Charges

Revenue
- Mill Operating Costs

Return for Processing Allowance
- Processing Allowance

Net Mill Return (i.e., value of the mill feed)

The processing allowance is determined as specified below but the amount deductible in any year cannot exceed 25% of the 'return for processing allowance'.

Depreciation Allowance: includes all capital expenditures except for exploration, research and working capital.

For capital expended during the preproduction development stage and for expansions of at least 25% in capacity, the deduction permitted is up to 100% of the allowable capital cost but not to be less than 5% per year.

Sustaining and other capital costs during the productive life of a mine are allowable at up to 33 1/3% per year on a straight-line basis with no minimum deduction.

New Brunswick (continued)

Assume maximum possible allowance is taken in each case.

Interest Allowance: 8% per year of the undepreciated cost of all assets qualifying for depreciation allowance. Note that it may in some cases be advantageous to depreciate more slowly than possible to take fuller advantage of this allowance.

Processing Allowance: annual rate applied to the original cost of processing assets but not to be less than 15 percent nor more than 65 percent of income for processing allowance.
8% of concentrator assets.
15% of smelting and refining assets.

New Brunswick Mining Tax:

income for mining tax	marginal rate
up to 100,000	exempt
100,000 and over	16%

Research Credit: 25% of research expenditures.

Quebec

Cash Flow Format:

Revenue
- Operating Cost
if negative: Carried Loss

Revenue
- Operating Cost
- Depreciation Allowance
- Exploration Expenditures
Income for Exploration and Investment Allowance
- Exploration and Investment Allowance
Income for Processing Allowance
- Processing Allowance
Income for Quebec Mining Tax
Quebec Mining Tax Otherwise Payable
- Carried Credit for Unused Exemption
- Deduction for Carried Loss
Net Quebec Mining Tax Payable
Refundable Credit

Depreciation Allowance: mine development capital costs at 100% per year; all other capital costs at 30% per year on a straight-line basis.

Exploration and Investment Allowance: $1 for every $3 of pre-production exploration expenditures, capital costs of processing facilities, and exploration costs incurred at operating underground mines*, up to a maximum or 33 1/3% of income for exploration and investment allowance in any year.

Processing Allowance: annual rate applied to the original cost of processing assets but not to be less than 15% nor more than 65% of income for processing allowance.
8% if ore concentrated
15% if concentrate is smelted and/or refined in Quebec

Rate applies to all processing assets up to and including final stage.

---

* Actually limited to a prescribed list of exploration expenditures which are a function of such factors as depth of exploration and distance from mine workings.

Quebec (continued)

The 15% rate applies to gold mill assets if the facility includes a smelter which produces doré or impure bullion.

Quebec Mining Tax Otherwise Payable:

income for mining tax	marginal rate
up to 500,000	exempt
500,000 and over	18%

At the 18 percent tax rate, the $500,000 exemption is equivalent to a credit of $90,000. Any part of the credit which is not used during a given year may be carried forward three years.

Deduction for Carried Loss: 18% of 'carried loss' in the year following the loss. This deduction can be carried back three years and ahead seven years.

Refundable Credit: 18 percent of the loss resulting from exploration expenditures and depreciation allowance during a given year, up to the limit of 18 percent of the loss incurred during the year.

Revenue
- Operating Cost
- Depreciation Allowance
- Exploration Expenditures

---

if negative; Loss Incurred During Year

Manitoba

Cash Flow Format:

Revenue
- Operating Cost

Net Income before Allowances
- Depreciation Allowance
- Exploration Expenditures

Income for Processing Allowance
- Processing Allowance

Income for Manitoba Mining Tax
Manitoba Mining Tax Otherwise Payable
Investment Tax Credit

Net Manitoba Mining Tax Payable

Depreciation Allowance: all capital costs at 20% per year on a declining-balance basis. The amount allowable must be reduced by the investment tax credit (see below).

Processing Allowance: average of 8% per year of the original cost of processing assets* but not to be less than 15% nor more than 65% of income for processing allowance.

Manitoba Mining Tax: 18% of income for Manitoba mining tax.

Investment Tax Credit: 5 percent of capital expenditures on mine development, mine plant and machinery, and processing assets, which have been made for the purposes of bringing a new mine into production, carrying out a major expansion, or 'modernizing' existing facilities to increase production potential.

Allowable capital costs for 'depreciation allowances' must be reduced by the amount of the investment tax credit.

The investment tax credit may be deducted in the year a qualified asset is acquired and can be carried forward for another five years.

---

* The May 1979 Manitoba budget increased the processing allowance rate from 8 percent to 10 percent per year but restricted the definition of processing assets to exclude common service facilities. Thus, assume 8 percent as an average rate on all processing assets.

Saskatchewan (metallic minerals excluding uranium)

Cash Flow Format:

Revenue
- Operating Cost

Net Income before Allowances
- Depreciation Allowance
- Exploration Expenditures

Income for Processing Allowance
- Processing Allowance

Income for Saskatchewan Mining Tax
Saskatchewan Mining Tax

Depreciation Allowance: mine development expenditures and mine plant and machinery capital costs allowable at 100%. Capital costs of processing, housing, and townsite facilities allowable at 30% per year on a declining-balance basis. For capital expenditures for road and power facilities, assume half is written off at 100%, and the other half at 30% per year declining balance. Assume 70% of infrastructure capital expenditures is deducted at 30% per year declining balance, and the remaining 30% of the infrastructure at 100%.

Processing Allowance: 8% per year of the original cost of processing assets but not to be less than 20% nor more than 65% of the income for processing allowance for copper-zinc deposits, and not to be less than 15% or more than 65% of income for other deposits.

Saskatchewan Mining Tax: 12.5% of income for Saskatchewan mining tax.

Alberta (metallic minerals)

Payout: date on which the cumulative gross revenue of the mine equals the sum of cumulative allowed capital costs, cumulative operating costs, cumulative on-site exploration and development costs, cumulative annual capital allowance, and cumulative pre-payout royalty.

Allowed Capital Costs: includes all capital expenditures directly attributable to the mine except for exploration expenditures, development costs, and working capital. Included in this category is an allowance for indirect capital costs of 1% of the capital costs incurred.

Operating Costs: includes smelting, refining, and transportation charges, and all other operating costs directly attributable to the mine.

Annual Capital Allowance: 15% of the unrecovered allowed capital costs in a year. Where the period to which the allowance applies is less than a full year, the allowance must be reduced to reflect the eligible period of the year.

Cash Flow Format: applies before payout is achieved, and defines mine mouth revenue after payout occurs.

Gross Revenue
- Smelting, Refining and Transportation Charges
- Mill Operating Costs
- Annual Capital Allowance on Processing Capital Expenditures

---

Mine Mouth Revenue

Alberta Pre-Payout Royalty: 1% of mine mouth revenue.

Cash Flow Format for Post-Payout Royalty: applies after payout occurs.

Gross Revenue
- Allowed Capital Costs
- Operating Costs
- On-Site Exploration and Development Costs

Revenue for Processing Allowance
- Processing Allowance
- Operating Losses from Prior Years
- Off-Site Exploration Costs

---

if negative, Carried Loss for Next Year
if positive, Net Revenue

Alberta (continued)

Allowed Capital Costs: permits 100% write down of allowed capital expenditures in the year of acquisition. Included in this category is an allowance for indirect capital costs of 1% of the capital costs incurred.

Processing Allowance: 10% per year of the original cost of processing assets but not to be more than 65% of the revenue for processing allowance.

Operating Losses: may be carried forward until recovered. The calculation of an operating loss excludes royalty paid.

Off-Site Exploration Costs: incurred in Alberta before the commencement of mining operations.

Alberta Post-Payout Royalty: the greater of 1% of mine mouth revenue or 12% of net revenue.

British Columbia

Cash Flow Format:

Revenue
− Operating Cost

Net Income before Allowances
− Depreciation Allowance
− Interest Payments
− Exploration Expenditures

Income for Earned Depletion Allowance
− Earned Depletion Allowance

Income for Processing Allowance
− Processing Allowance

Income for British Columbia Mining Tax
British Columbia Mining Tax

Depreciation Allowance: applies to all capital costs. Calculated in the same manner as explained under 'capital cost allowance' and 'development expenditures' for federal corporate income tax.

Earned Depletion Allowance: calculated in the same manner as explained for federal corporate income tax.

British Columbia (continued)

Processing Allowance: 8% per year of the original cost of processing assets but not to be less than 15% nor more than 50% of income for processing allowance.

British Columbia Mining Tax: 17.5% of income for mining tax.

Note: all allowances must be taken on an individual project basis.

Northwest Territories

Cash Flow Format:

Revenue
- Operating Cost

Net Income before Allowances
- Depreciation Allowance
- Exploration Expenditures

Income for Processing Allowance
- Processing Allowance

Income for Northwest Territories Mining Tax
Northwest Territories Mining Tax

Depreciation Allowance: all capital costs except post-production mine development capital costs allowable at 15% per year on a straight-line basis; post-production mine development capital costs at 100%.

Processing Allowance: 8% per year of the original cost of processing assets but not to be less than 15% nor more than 65% of the income for processing allowance.

Northwest Territories Mining Tax:

income for mining tax	marginal rate
up to 10,000	exempt
10,000 - 1 million	3%
1 million - 5 million	5%
5 million - 10 million	6%
10 million and over	+ 1% for each additional $5 million up to 12% maximum

Yukon Territory

Cash Flow Format:

Revenue
− Operating Cost

Net Income before Allowances
− Depreciation Allowance
− Exploration Expenditures

Income for Yukon Mining Tax
Yukon Mining Tax

Depreciation Allowance: all capital costs except post-production mine development capital costs allowable at 15% per year on a straight-line basis; post-production mine development capital costs at 100%.

Yukon Mining Tax:

income for mining tax	marginal rate
up to 10,000	exempt
10,000 - 1 million	3%
1 million to 10 million	5%
5 million - 10 million	6%
10 million and over	+ 1% for each additional $5 million up to 12% maximum

Rates Used to Calculate Tax Credits Associated with Exploration Expenditures

Ontario	63.7%	(allows for percentage depletion in Ontario corporate income tax)
Newfoundland	66.0%	
Nova Scotia	64.0%	
New Brunswick	73.7%	(allows for special exploration write-off)
Quebec	57.5%	
Manitoba	69.0%	
Saskatchewan	63.5%	
Alberta	57.0%	
British Columbia	65.6%	
Northwest Territory	50.0%	(assumes 6% mining tax rate)
Yukon Territory	50.0%	(assumes 6% mining tax rate)

Weighted Averages

Shield Region	60.5%
Canada	61.5%

THE AUTHORS

Brian Mackenzie is a senior research associate of the Centre for Resource Studies and a professor in the Department of Geological Sciences at Queen's University. He received his formal education in mining engineering and mineral economics at McGill University, the University of the Witwatersrand, and Columbia University. In his early years, he worked for Sheep Creek Mines, Union Corporation, the South African Department of Mines, and Energy, Mines and Resources Canada. From 1968 to 1977 he was responsible for teaching and research in mineral economics and was director of the mining program at McGill University. He joined Queen's University in 1978. Dr. Mackenzie has carried out a wide range of assignments on mineral policy and planning issues for mining companies, governments, and international agencies. In 1977 he was named distinguished lecturer in mineral economics by the Canadian Institute of Mining and Metallurgy, and in 1983 he received their "Robert Elver Mineral Economics Award". He has presented mineral economics seminars in Canada, Australia, Brazil, Chile, China, Finland, Greece, Indonesia, South Africa, Sweden, Tanzania, and the United States.

Michel Bilodeau was born in Montreal in 1948. He graduated in 1970 from Ecole Polytechnique with a bachelor's degree in geological engineering. He then received the degrees of M.Sc. (App.) in mineral exploration and Ph.D. in mineral economics from McGill University. Dr. Bilodeau is an associate professor in the Department of Mining and Metallurgical Engineering at McGill University. He is also a faculty associate of the Centre for Resource Studies. Dr. Bilodeau specializes in quantitative methods of analysis, computer modelling, geostatistics, and mineral economics.

Michael Doggett is a research associate of the Centre for Resource Studies at Queen's University. He holds a B.Sc. (honours) in geology from Mount Allison University and an M.Sc. in mineral economics from Queen's University where he is currently enroled in a Ph.D. program. His background includes mineral exploration in Canada and Australia as well as extensive research into the economics of gold mining in Canada. Present interests and research focus on the costs and benefits associated with the global emphasis on exploration and development of gold deposits.

THE CENTRE FOR RESOURCE STUDIES

The Centre for Resource Studies (CRS) was established in 1973, under the sponsorship of Queen's University, the federal Department of Energy, Mines and Resources, and The Mining Association of Canada, to carry out a program of research and publication on mineral policy issues.

The Centre provides opportunities for multidisciplinary research in resource studies at Canadian universities, furnishes reliable information on matters related to mineral resource policy, and promotes closer liaison between government, industry and other concerned groups. The research program is carried out both at the Centre and by means of contracts with qualified investigators, usually at Canadian universities. Small exploratory studies are also funded, through a system of grants-in-aid of research. CRS Policy Discussion Seminars involve representatives from governments, industry, universities, labour, and other interested groups in working sessions on issues of current concern. Through this program of research and seminars, and the resulting publications, the Centre contributes to informed discussions and a better understanding of significant issues.

The Centre is governed by a Board of Directors which establishes general policy and priorities for research. The chairman is Dr. C.G. Miller and the executive director is Mrs. Margot Wojciechowski. There are fourteen other members - seven nominated by Queen's University, four by The Mining Association of Canada, and three by the federal government. Guidance on the research program, together with discussion of policy issues and other matters, is provided by the Advisory Council. This body comprises all researchers associated with the Centre, together with members appointed from such groups as governments, industry, labour, and other interests. A Research Advisory Committee aids in the development of projects and the selection of research proposals. The executive director and staff are responsible for the work of the Centre within this framework.

Most of the funding for the Centre's activities is provided by the sponsors. In addition, the Centre accepts contracts from other organizations interested in mineral policy research.

The Centre welcomes comments on its publications, proposals for research projects or for publication, or enquiries about any aspect of its work. For further information, contact:

Centre for Resource Studies
Queen's University
Kingston, Ontario, Canada K7L 3N6
(613) 545-2553

CRS PUBLICATIONS

Monographs and Collections

Conflict and its Resolution in the Administration of Mineral Resources in Canada, by R.M. Burns; 62 pp, 1976.

The Impact of the Mining Industries on the Canadian Economy, by R.W. Boadway and J.M. Treddenick; 116 pp, 1977.

The Transportation Impact of the Canadian Mining Industry, by A.I. Wallace; 154 pp, 1977.

Human Resources in Canadian Mining: A Preliminary Analysis, by J.A. MacMillan, G.S. Gislason, And S. Lyon; 174 pp, 1977.

Health and Safety in the Canadian Mining Industry, by G.W. Gibbs and P. Pintus; 248 pp, 1978.

The Canadian Nonferrous Metals Industry: An Industrial Organization Study, by E. Urquhart; 158 pp, 1978.

Economic Impacts and Linkages of the Canadian Mining Industry, by P.E. Nickel, et al; 140 pp, 1978.

Environmental Impact of Mining in Canada, by E.A. Ripley, et al; 274 pp, 1978.

Effects of Taxation on Base Metal Mining in Canada, by B.W. Mackenzie and M.L. Bilodeau; 188 pp, 1979.

Gold: The World Industry and Canadian Corporate Strategy, by E. Cousineau and P.R. Richardson; 192 pp, 1980.

The Impact of Policy Change on Decisions in the Mineral Industry: The Case of Exploration in Manitoba, 1969-77, by B.E. Owen and W.J. Kops; 116 pp, 1980.

The Role of Mineral Taxation in Industry/ Government Conflict: The Case of the Saskatchewan Potash Reserve Tax, by D.L. Anderson; 135 pp, 1981.

Profitability in the Canadian Mineral Industry, by C.H. Pye; 178 pp, 1981.

Foreign Investment Control in the Canadian Mineral Sector: Lessons from the Australian Experience, by D.L. Anderson; 180 pp, 1983.

Financing Canadian Mining in the Eighties: Strategies for Action, edited by D. Yudelman; 240 pp, with papers by B. Bradley, A. Dorland, J. Erola, P. Gillin, S. Greenwald, B. Kalymon, P. MacCulloch, B. Mackenzie, K. Murphy, A. Powis, R. Sultan, and D. Yudelman, 1984.

National Resources and International Bargaining Power: Canada's Mineral Policy Options, by P.J. Caragata; 190 pp, 1984.

Canadian Mineral Policy Past and Present: The Ambiguous Legacy, by D. Yudelman, 192 pp, 1985.

Canada and International Mineral Markets: Dependence, Instability, and Foreign Policy, by M. Webb and M. Zacher, 194 pp, 1988.

An Analysis of Japanese Coking Coal Procurement Policies: The Canadian and Australian Experience, by D.L. Anderson, 221 pp, 1987.

The Korean Mineral Market: Opportunities and Marketing Strategies for Canada, by O.Y. Kwon, 177 pp, 1987.

Mining Potential in Northern and Southern Canada: Guidelines for Regional Development Policy, by L.J. Verleun, and B.W. Mackenzie, 225 pp, 1988.

Pricing of Metals, by M.E. Slade, 149 pp, 1988.

Metals Demand and the Canadian Metal Industry: Structural Changes and Policy Implications, by C. Nappi, 145 pp, 1989.

Proceedings

No. 2 International Competition and the Canadian Mineral Industries, with papers by H.C. Armstrong, H.T. Fargey, C.G. Miller, N.D. Olewiler and P.R. Richardson, D. Perlstein, and K.C. Hendrick; 109 pp, 1978.

No. 3 Current Concerns in Mineral Policy, with papers by C.R. Archibald, W.J. Barbour, D.B. Brooks, J.S. Dowsett, J.M. Fleming, and G.A. Jewett; 75 pp, 1978.

No. 4 Canada's Mineral Trade: Implications for the Balance of Payments and Economic Development, with papers by B.W. Wilkinson, D.J. McCulla, J.G. MacKinnon, A.G. Balogh, W.G. Chambers and J.S. Reid; 113 pp, 1978.

No. 5 Employee Relations Initiatives in Canadian Mining, with papers by W.J. Bennett, F.R. Nogas and J.P. Fulcher, W.F. Clarke, S.B. Jones, T.F. Cawsey and P.R. Richardson, and P. Warrian; 85 pp, 1979.

No. 7 The Future for Junior Mining in Canada, with papers by Hon. J.A.C. Auld, J.L.C. Lyndon, N.B. Keevil Jr., D.G.C. Menzel, H.T. Fargey, A.J. Freyman, John. R. Hnatyshyn, J.C. Baillie, D.W. Scrim, J.P. Bunting, E.H. Neave and P.R. Richardson, L.A. English, M. St.-B. Harrison, R.H. Grasley, and Hon. F. Drea; 125 pp, 1979.

No. 8 Mining-Linked Diversification of the Sudbury Basin Economy, with papers by D.C. Frith, J.P. Remy, A.I. Wallace, J.H. Holtby and L.C. Kitchener; 53 pp, 1980.

No. 10 Northern Mining in the 80s, with papers by G. Braden, R.J. Cathro, D. MacKinnon, J. Smith, R.W. Stephenson, B.E. Novak, E.N. Doyle, J.R. Witty, J.E. Marshall, A.G. Gordon, J. McCormack, H.B. Hicks, J. Zigarlick, T. Shearcroft, W. Kupsch, J. Stabler, J. Erola; 110 pp, 1980.

No. 11 **Skilled Manpower Shortages in the 1980s: Towards a Cooperative Solution**, with papers by R.J. Gray, J.S. Reid, W.H. Digby, J.R. Hopkinson, A. Knoll, O. Tremblay, G. Betcherman, P.E. Womersley, M.J. Alton, V.C. Allman, C. Stairs, E.J. Weiss, and W.E. McBride; 116 pp, 1981.

No. 12 **Acid Rain Controls and the Economics of the Canadian Nonferrous Mineral Industry**, with papers by J. Gerin, W.G. Deeks, P.R. Clarke, J.B. Hyne, H.T. Fargey, B.W. Mackenzie, and E.J. Ward; 90 pp, 1982.

No. 13 **Mineral Policy Formulation: The Role of Scientific and Technical Knowledge**, with papers by B. Mackenzie, G.A. Jewett, H.D. Dreschler, P.G. Halkett, D.E. Bond, D.C. Findlay, W.G. Jeffery, L.G. Bonar, D.W. Davis, J. Zwartendyk; 135 pp, 1982.

No. 15 **Native Participation in Mineral Development Activities**, edited by M.J. Wojciechowski, with papers by A. Clark and M. Lalonde, K.A. Graham, B.W. Mackenzie, C.D. Hunt, J-L Blais, F.R. Joubin, E. Laliberte; 150 pp, 1984.

No. 16 **Mining Productivity**, edited by M.J. Wojciechowski, with papers by P.R. Richardson, K. Stollery, H. Martin, B.W. Mackenzie, C.G. Miller, W. James, P. Lepage, K. Whitham, W. Curlook, and E. Kossatz; 187 pp, 1985.

No. 17 **Canadian Mining Taxation**, edited by M.J. Wojciechowski, with papers by G. Langlois, D. Williams, T. Enemark, P. Halkett, R. Albert, K. Service, K. O'Brien, R. Boadway, J. Mintz; 144 pp, 1985.

No. 18 **Structural Changes in the World Mineral Industry: Implications for Canada**, edited by M.J. Wojciechowski, with papers by P. Crowson, S. Hunt, G. Haclin, J. Davies, D. Karvonen, G. Denis, D. Daly, D. Haglund, I. Bennett, G. Mahoney, K. Buck, 213 pp, 1986.

No. 19 **Technology Policies in the Canadian Mineral Industry**, edited by M.J. Wojciechowski, with papers by R. Woodbridge, M.J. Wojciechowski, F. Pickard, D. Bevelander, J. Hood, W.G. Jeffery and J. Kuryllowicz, P. Richardson, J. Schade, W. Curlook, and G. Miller, M. Sayer, G. Hatch, D. Hutchinson, and A. Molinari, 179 pp, 1986.

No. 20 **Long-Term Prospects for Gold Mining**, edited by B.W. Mackenzie and R. Gesing, with papers by J. Nichols, T. Green, J. Fisher, M. Murenbeeld, G. Anders, R. Woodall, D. Krige, D. Cranstone, B. Mackenzie, M. Doggett, B. Kalymon, C. Margueron, M.J. Wojciechowski, and W.K. Buck, 233 pp, 1987.

No. 21 **Prospects for Minerals in the 90s**, edited by P.R. Richardson and R. Gesing, with papers by P.R. Richardson, N. Keevil Jr., J. Macleod, J. Cordes, S. Hunt, J. Zwartendyk, P. Perron, P. McGeer, B. Harris and A. Cecutti, and R. Gesing and M.J. Wojciechowski, 149 pp, 1988.

Working Papers

No. 8 **Federal Mineral Policies: 1945-75**, by M.J. Wojciechowski; 85 pp, 1979.

No. 9 **Trends in Canada's Mineral Trade**, by B.W. Wilkinson; 63 pp, 1978.

No. 10 **Canada as a World Zinc Producer: Prospects to 1980**, by N.D. Olewiler, P.R. Richardson, and L. Rumble; 22 pp, 1978.

No. 13 **Cerro Colorado: A Case Study of the Role of Canadian Crown Corporations in Foreign Mineral Development**, by C.G. Miller, N.D. Olewiler, and P.R. Richardson; 44 pp, 1979.

No. 15 **Public Policy Aspects of Information Exchange in Canadian Mineral Exploration**, by D.O. Downing and B.W. Mackenzie; 52 pp, 1979.

No. 16 **Canada's Competitive Position in Copper and Zinc Markets**, by B.W. Mackenzie; 41 pp, 1979.

No. 17 **Constitutional Change and the Mineral Industry in Canada**, by W. MacDonald; 66 pp, 1979.

No. 18 **An Economic Analysis of the Canadian Taxation of an Integrated Mining Company**, by J.-T. Bernard; 112 pp, 1980.

No. 20 **The Market Price of Risk in the Canadian Mining Industry**, by H.F. Campbell, 29 pp, 1980.

No. 21 **Public Affairs and the Minerals Industry: Junior Mining; Northern Development; Loans for Foreign Mines; A Public Relations Strategy**, by C.G. Miller, 42 pp, 1980.

No. 22 **Newfoundland Mining Industry: Present Status and Potential for Expansion**, by N.D. Olewiler and C.H. Pye; 208 pp, 1980.

No. 23 **Effects of Water Pollution Control Costs on Base Metal Mining in Canada**, by N.A. Papanicolaou and B.W. Mackenzie, 74 pp, 1981.

No. 24 **The Costs of Uncertainty: Regulating Health and Safety in the Canadian Uranium Industry**, by I. Robinson; 74 pp, 1982.

No. 25 **Economic Guidelines for Small Mineral Deposits/Directives economiques relatives aux petits gisements**, by B.W. Mackenzie and M.L. Bilodeau; 66 pp, 1982.

No. 28 **Economic Mineral Exploration Targets**, by B.W. Mackenzie; 72 pp, 1984.

No. 30 **Canadian Mineral Policy Formulation: A Case Study of the Adversarial Process**, by D. Yudelman, 83 pp, 1984.

No. 31 **Federal Policy and the Role of the Public Enterprise in the Mining Sector**, by M.J. Prince and G.B Doern, 52 pp, 1984.

No. 32 **Productivity and Price: The Case of Gold in Ontario**, by A.G. Green, 54 pp, 1984.

No. 33 **The Origins of Public Enterprise in the Mineral Sector: Three Provincial Case Studies**, by M.J. Prince and G.B. Doern, 143 pp, 1985.

No. 34 **Mining and the Macdonald Commission: The State of the Industry in the Mid-1980s**, by D. Yudelman, 116 pp, 1985.

No. 35 **Effects of Location on the Competitive Position of Mineral Exploration and Development Opportunities in Canada**, by B.W. Mackenzie, D.W. Davis and M.L. Bilodeau; 72 pp, 1986.

No. 36 **Mine Infrastructure and Economic Development in North Australia**, by C. O'Faircheallaigh, 104 pp, 1986.
No. 37 **Intergovernmental Mineral Commodity Arrangements**, by W.K. Buck; 70 pp, 1986.
No. 38 **Value-Added Taxation: Issues and Impact for Canadian Mines**, by B.J. Dyack; 62 pp, 1986.
No. 39 **Flow-Through Share Financing**, by B. Kalymon; 63 pp, 1987.
No. 40 **Mineral Exploration Economics: The Search for Base Metals in Australia and Canada**, by B.W. Mackenzie and R. Woodall; 112 pp, 1987.
No. 41 **Economic Trends in Canadian Gold Supply**, by B.W. Mackenzie and M. Doggett; 80 pp, 1987.
No. 42 **The Changing Transportation Environment of the Canadian Mineral Industry**, by I. Wallace; 37 pp, 1987.
No. 43 **Long Distance Labour Commuting in the Canadian Mining Industry**, by K. Storey and M. Shrimpton; 45 pp, 1989.

Technical Papers

No. 2 **Economic Effects of Smelter Controls on the Canadian Nonferrous Mining Industry**, by B.W. Mackenzie and M. Bilodeau; 162 pp, 1982.
No. 3 **Secondary Supply of Copper and Ferrous Metals and Canadian Metal Markets**, by K.R. Stollery, 118 pp, 1983.
No. 4 **Mineral Technology Transfer: Evaluation of the CANMET Pit Slope Project**, by B.W. Mackenzie and R. Pakalnis, 200 pp, 1985.
No. 6 **Geological Aspects of Mining Productivity**, by B.W. Mackenzie, 115 pp, 1985.
No. 7 **Innovation in the Mineral Industry: Opportunities and Strategies for Canada**, by M.J. Wojciechowski and P.R. Richardson, 278 pp, 1987.
No. 8 **An Inter-Sectoral Study of Canada's Resource Industries**, by T. Bennett and D.L. Anderson; 197 pp, 1988.
No. 9 **Mineral Exploration and Mine Development Potential in Ontario: Economic Guidelines for Government Policy**, by B.W. Mackenzie, M.L. Bilodeau and M. Doggett; 194 pp, 1989.

Mineral Policy Updates

Mineral Policy Update: 1981, by M.J. Wojciechowski and C.E. McMurray; 85 pp, 1983.
Mineral Policy Update: 1982, by M.J. Wojciechowski and C.E. McMurray; 88 pp, 1983.
Mineral Policy Update: 1983, by M.J. Wojciechowski; 88 pp, 1984.
Mineral Policy Update: 1984, by M.J. Wojciechowski; 118 pp, 1985.

Eastern Arctic Study
(Published jointly by the Centre for Resource Studies and the Institute of Local Government)

The Inuit Land Claim, Constitutional Development, and Local Government Reform in the Northwest Territories: An Overview, by K.A. Graham and A.B. McAllister, 50 pp, 1981.
Eastern Arctic Study Case Study Series: Mineral Exploration in the Baker Lake Area, by A.B. McAllister, 58 pp, 1982.
Eastern Arctic Study Case Study Series: The Nanisivik Mine, by M.J. Wojciechowski, 62 pp, 1982.
Eastern Arctic Study Annotated Bibliography, M.P.S. Brown, 68 pp, 1984.
A Climate for Change: Alternatives for the Central and Eastern Arctic, by K.A. Graham, M.P.S. Brown, A.B. McAllister, and M.J. Wojciechowski, Final Report of the Eastern Arctic Study, 198 pp, 1984.